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UNIT COAL AND THE COMPOSITION OF COAL ASH

BY

S. W. PARR

AND

W. F. WHEELER

UNIVERSITY OF ILLINOIS

ENGINEERING EXPERIMENT STATION

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UNIT COAL AND THE COMPOSITION OF COAL ASH

BY S. W. PARR, PROFESSOR OF APPLIED CHEMISTRY
AND
W. F. WHEELER, FIRST ASSISTANT, DEPARTMENT OF CHEMISTRY,
ENGINEERING EXPERIMENT STATION

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I. Introduction[1]

It was recognized at the very outset of these experiments on coal, which were begun in the Laboratory of Industrial Chemistry, University of Illinois, about the year 1897, that much value would attach to any device or method which would make it possible to study the properties, composition, heat values, etc., of the pure coal substance as distinct from the non-coal material with which it is associated. While much data of a general nature accumulated from year to year, having more or less bearing upon this subject, it was not until recent months that a definite study of the problem was undertaken. It is the purpose of this paper to present the results of these investigations upon the properties and more definite determination of actual or unit coal. By unit coal is meant the organic material which is involved in combustion as apart from the mineral constituents which are the extraneous and variable accompaniments of the actual or unit coal.

II. Historical Review

A number of investigators have worked on various phases of this topic. Lord and Haas, who were no doubt the first in the field, have developed the idea that in any given type of coal, or perhaps, less broadly, in any given deposit of coal, there exists an initial substance, with certain uniformities as to calorific value, which might make it possible to calculate the heat units for any sample whose source as to locality was known.

From numerous analyses of Pennsylvania and Ohio coals, Lord and Haas draw a comparison between the heat values as derived by Du Long's formula, the Mahler calorimeter, and those calculated from unit value which they designate as H, and describe as being the value for the ash, water and sulphur-free substance. They find the sulphur to be a disturbing element and correct for it in a partial manner only. However, they state as their conclusion that "On comparing the results, seam by seam, it would appear

[1]Credit is due Mr. W. F. Wheeler for the greater part of the work embodied in this bulletin. Mr. Wheeler died November 18, 1909.

that the actual coal of a given seam, at least over considerable areas, may be regarded as essentially of uniform heating value."[1]

The expression "actual coal" presumably refers to this same initial or unit substance free from extraneous matter, such as ash, moisture and sulphur. The same idea is evidently intended in the quotation below, though the same qualification as to "actual coal" is not used, thus, "The results of our tests seem to indicate the interesting conclusion that the character of a coal seam, so far as its fuel value is concerned, is a nearly constant quantity over considerable areas. The determination of the value for seams would be of great use, as the rapid proximate analysis, or, for that matter, merely the determination of ash and moisture in low sulphur coals, would be sufficient to grade coals of the same vein. Of course, it is dangerous to argue from so few samples, but the proposition seems reasonable. At least, we hope that further work may confirm these conclusions."

Kent, in discussing this paper, in the same volume, page 946, says, "The conclusions of the authors that the 'actual' coal (moisture and ash excluded) of a given seam over considerable areas, may be regarded as of uniform heating value, is one of great practical importance. I have held the same opinion tentatively for a long time. . . ."

Contemporaneous with the work of Lord and Haas was that of W. A. Noyes.[2] As a result of 21 calorimetric determinations on Indiana and Pittsburgh bituminous coals, he says, "The heating effect may be found, in all cases examined, with a maximum error of 2 per cent, by the following rule: Subtract from 100 the per cents of moisture, ash, and one half the per cent of sulphur, and multiply the remainder by 80.7. The product will be the heating effect of the coal burned to vapor of water, expressed in calories."

Whatever value may have attached to these propositions, the matter seems to have lain more or less dormant until the subject

[1]Trans. Am. Inst. Min. Eng. 27; 259, 1898.
[2]Jour. Amer. Chem. Soc. 20; 285, 1898.

was brought again to the surface by Mr. A. Bement, who has in numerous articles insisted upon its great practical value, as, for example, referring to the advantage of having certain units of reference, he says, "The possibility of the more extended use of constants is presented and the author urges the feasibility of considering the pure coal compositions as constants for a coal seam or particular locality of such seams. This possibility has been suggested, principally by the fact that the heating power of the pure coal from a general locality does not vary over greater limits than that of the calorimetric method, and he has been able to employ it as a constant in calculating the heating power of dry and moist coal, having determined only moisture and ash, and obtained results that check with calorimetric determinations made on the same samples. The author, however, does not claim originality in this observation, but does insist that the use of such constants is of advantage....This view concedes that coal from a certain locality or seam does not vary in quality, but that the variation is due to the presence of ash and moisture which are impurities associated with the coal."[1]

In a subsequent paper,[2] he argues for the same constancy of values when referred to the pure coal basis. These considerations have, no doubt, led Mr. Bement and others to adopt the term "pure coal" as expressive of this idea of constancy in the "ash and water-free" substance, in addition to the fact of its being a more compact and convenient term to use.

In all of these discussions relating to the uniformity of values for the actual coal, it is evident that if there are any constituents that fail of recognition to the extent that they are not included among the factors for mineral or non-coal material, but on the contrary, are included in the actual coal substance, then the question arises as to whether we yet have a fair basis of reference for drawing conclusions as to the constancy or the degree of agreement which we may properly credit to the actual coal constituent.

[1]Jour. Am. Chem. Soc. 28; 636.
[2]Jour. Western Society of Engineers 11; 757.

For example, the coals of the Mississippi Valley may have as high as 4 or even 8 per cent of sulphur. Indeed, variations of 1 to 3 per cent may be possible within the product from the same mine, especially where the washing of the coal is in vogue. Now if this variable is counted as part of the "actual coal," it by so much prohibits any uniformity of heat values being credited to this hypothetical substance we call "unit coal." This phase of the subject was touched upon in the discussion[1] accompanying the paper by Mr. Bement already mentioned. It was there urged that not only the sulphur, but certain volatile constituents were present which escaped determination as part of the ash, and were, therefore, included in the actual coal, thus introducing a variable which prevented accurate study of that substance. Shortly afterward, analytical evidence in support of this idea was developed by Mr. Wheeler,[2] and the results of his investigation were published in 1908. The essential point developed in that work was the evidence of the existence of a non-coal constituent which by the ordinary methods of analysis not only escapes recognition and measurement, but is counted as part of the true coal substance. This is the water of hydration or other volatile matter chemically combined with the mineral or ash substance in such a manner as to be driven off only at a red heat. For example, if the shale content of the ash has 8 per cent combined water, and the same is not counted with the ash but as part of the "volatile combustible," here is a variable which by so far keeps us from coming at the correct value for the actual or unit coal. Similar variables would accompany the presence of gypsum whose water of crystallization in the process of analysis would take its place as part of the pure coal substance. Calcium carbonate also would afford a similar variable in so far as it would lose carbon dioxide in the process of analysis. It should be noted here that Taylor and Brinsmaid have proposed a graphical method for arriving at unit coal values which, though empirical and consequently indi-

[1]Parr; Jour. Western Society of Engineers 11; p. 762, 1906.
[2]Trans. Am. Inst. Min. Engs., Vol. 38, p. 621, 1908.

rect in character, is very ingeniously devised and no doubt is of much practical value.[1]

III. Experimental Data

It is the purpose of this paper to present the results of our own investigations, together with such applications as the data at hand will permit, in the hope that the facts presented may indicate the possibility of arriving directly at the determination of all of the non-coal or mineral constituents, including those more volatile mineral compounds which have heretofore been associated in analytical processes with the fuel. The fact should be especially emphasized that it has been the purpose of the investigation to arrive, first, at an exact determination of the inorganic component of the coal as distinct from the organic material, and, second, to study the constancy of composition of this organic substance as indicated by its heat content. Only in this manner can we arrive at a conclusion as to whether or not it has properties which will warrant its use as a fuel unit. Manifestly, therefore, the sulphur should be excluded from this unit. In so far as sulphur occurs in the form of iron pyrites, and this includes the major part, it is extraneous in character and bears no constant ratio to the amount of organic matter present.

For the purpose of illustrating by specific instances the effect of including such variable constituents as sulphur, etc., in the combustible matter, instead of in the ash, and so allowing them to augment falsely the actual coal substance, the following experimental procedure was followed:

A given sample of the coal was separated into two divisions of high and low ash content in a solution of zinc sulphate of 1.35 specific gravity, whereby that part of the coal with low ash and less pyrites was separated by floating from the heavier particles with higher ash and more sulphur, the latter sinking to the bottom. Now, upon the hypothesis that the "actual coal" in these

[1]Jour. Ind. and Engrg. Chem. Vol. 1, Feb. 1909.

two divisions of the same sample should have the same heat value, the subjoined table is arranged to show what widely divergent values may be indicated by reason of different methods of arriving at the "actual coal" constituent. If everything excepting the ash as weighed and the moisture be credited to this material, there will result unit values, as shown under column (*a*) of the subjoined Table 1, which is the "pure coal" of Mr. Bement. If we take out the heat due to sulphur, and correct the remaining value for ash as determined, plus moisture, plus all of the sulphur, there will result values as shown in column (*b*), which would be the results as derived by means of the method of Lord and Haas. If we calculate the indicated values to the material as free from ash and moisture and correct also for one-half of the sulphur, there will result values, as shown under column (*c*), which would conform to the method as suggested by Dr. Noyes.

In column (*d*) we have results from the method of calculation which subtracts the heat due to the sulphur, corrects the ash for the sulphur, and also adds a uniform amount for hydration or volatile inorganic matter, amounting to 8 per cent calculated upon the corrected ash free from iron pyrites, assuming all of the sulphur to be in that form. A tabular statement, therefore, for these four different methods of calculation would be as follows:

(*a*) According to Bement

$$\frac{\text{B. t. u. as indicated}}{1.00 - (\text{Moisture} + \text{Ash as weighed})}$$

(*b*) According to Lord and Haas

$$\frac{\text{B. t. u.} - 4050\ \text{S}}{1.00 - (\text{Moisture} + \text{Ash as weighed} + \text{Sulphur})}$$

(*c*) According to Noyes

$$\frac{\text{B. t. u. as indicated}}{1.00 - (\text{Moisture} + \text{Ash as weighed} + 1/2\ \text{Sulphur})}$$

(*d*) According to Parr and Wheeler

$$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - [\text{Moisture} + \text{Ash} + 5/8\ \text{S} + .08\ (\text{Ash} - 10/8\ \text{S})\ ]}$$

TABLE 1

COMPARATIVE VALUES OF "ACTUAL COAL"

Tab. No.	Lab. No.	Description of Sample	Oven-dry Coal: Ash	Oven-dry Coal: Sul.	Oven-dry Coal: Iron	Oven-dry Coal: B. t. u.	Heat Value of "Actual Coal" as Calculated by Different Methods: (*a*) Non-coal as Ash only (uncorrected) Ref. to Indicated B. t. u.	Diff.	(*b*) Non-coal as Ash (uncorrected) + Sulphur Ref. to B. t. u. − 4050 S.	Diff.	(*c*) Non-coal as Ash + ½ Sulphur Ref. to B. t. u. as Indicated	Diff.	(*d*) Non-coal as 1.08 × Ash + 22/40 S. Ref. to B. t. u. − 5000 S.	Diff.
1		Sangamon Co., Ill., Lump Coal:												
	6130	(*a*) Untreated	11.66	5.99	3.38	12356	13987		14709		14477		14331	
	6131	(*b*) Floated, Sp. Gr. less than 1.35	6.12	3.20	.65	13300	14164	+177	14523	−186	14412	−65	14340	+ 9
2		Sangamon Co., Ill., Screenings:												
	6122	(*a*) Untreated	18.21	4.25	2.37	11478	14031		14709		14428		14442	
	6123	(*b*) Floated, Sp. Gr. Less than 1.35	8.13	2.95	.70	13043	14192	+161	14534	−175	14407	+21	14392	−50
3		Williamson Co., Ill., Washed Nut:												
	6290	(*a*) Untreated	12.83	1.85	1.09	12523	14361		14593		14519		14603	
	6121	(*b*) Floated, Sp. Gr. less than 1.35	4.01	1.39	.54	13929	14509	+148	14664	+ 71	14615	+96	14602	− 1
4		LaSalle Co., Ill., Washed Screenings:												
	6129	(*a*) Untreated	10.05	3.43	2.32	12885	14316		14616		14602		14566	
	6128	(*b*) Floated, Sp. Gr. less than 1.35	3.94	2.33	1.29	13922	14487	+171	14754	+138	14680	+78	14615	+49

TABLE 1

COMPARATIVE VALUES OF "ACTUAL COAL"—(*Continued*)

Tab. No.	Lab. No.	Description of Sample	Oven-dry Coal				Heat Value of "Actual Coal" as Calculated by Different Methods							
			Ash	Sul.	Iron	B. t. u.	(*a*) Non-coal as Ash only (uncorrected) Ref. to Indicated B. t. u.	Diff.	(*b*) Non-coal as Ash (uncorrected) + Sulphur Ref. to B. t. u. − 4050 S.	Diff.	(*c*) Non-coal as Ash + ½ Sulphur Ref. to B. t. u. as Indicated	Diff.	(*d*) Non-coal as 1.08 × Ash + 22/40 S. Ref. to B. t. u. − 5000 S.	Diff.
5		Vigo Co., Ind. Nut:												
	6132	(*a*) Untreated	16.84	7.62	5.17	11790	14170		15230		14858		14698	
	6133	(*b*) Floated, Sp. Gr. less than 1.35	4.27	3.08	1.06	13870	14478	+308	14836	−394	14725	−133	14638	− 60
6		Sullivan Co., Ind. Lump:												
	6135	(*a*) Untreated	6.11	3.37	2.24	13664	14551		14944		14819		14741	
	6134	(*b*) Floated, Sp. Gr. less than 1.35	2.53	1.29	.36	14259	14624	+ 73	14771	−173	14820	+ 1	14700	− 41
7		Franklin Co., Ill., Face sample:												
	471	(*a*) Sp. Gr. greater than 1.35	18.00	.57	Not Det.	11639	14194		14236		14244		14467	
	463	(*b*) Sp. Gr. less than 1.35	4.64	.54		13765	14435	+241	14492	+229	14476	+232	14513	+ 46
8		Franklin Co., Ill., Face sample:												
	536	(*a*) Sp. Gr. greater than 1.35	14.43	1.45	"	12142	14190		14495		14310		14433	
	464	(*b*) Sp. Gr. less than 1.35	3.83	.71	"	13918	14472	+282	14550	+ 60	14525	+215	14541	+108

TABLE 1

COMPARATIVE VALUES OF "ACTUAL COAL"—(*Concluded*)

Tab. No.	Lab. No.	Description of Sample	Oven-dry Coal				Heat Value of "Actual Coal" as Calculated by Different Methods							
			Ash	Sul.	Iron	B. t. u.	(*a*) Non-coal as Ash only (uncorrected) Ref. to Indicated B. t. u.		(*b*) Non-coal as Ash (uncorrected) + Sulphur Ref. to B. t. u. − 4050 S.		(*c*) Non-coal as Ash + ½ Sulphur Ref. to B. t. u. as Indicated		(*d*) Non-coal as 1.08 × Ash + 22/40 S. Ref. to B. t. u. − 5000 S.	
								Diff.		Diff.		Diff.		Diff.
9		Perry Co., Ill., Face sample:												
	472	(*a*) Sp. Gr. greater than 1.35....................	22.17	1.15	"	10922	14033		14183		14136		14405	
	465	(*b*) Sp. Gr. less than 1.35...	4.22	.86	"	13763	14369	+336	14464	+281	14434	+298	14446	+41
10		Perry Co., Ill., Face sample:												
	537	(*a*) Sp. Gr. greater than 1.35....................	9.52	.65	"	12947	14309		14384		14360		14452	
	466	(*b*) Sp. Gr. less than 1.35...	2.66	.74	"	13985	14367	+ 58	14430	+ 46	14422	+ 62	14421	−31
11		Williamson Co., Ill., Face sample:												
	473	(*a*) Sp. Gr. greater than 1.35....................	17.75	1.15	"	11766	14306		14451		14405		14599	
	467	(*b*) Sp. Gr. less than 1.35...	4.08	.99	"	13942	14535	+229	14644	+193	14617	+212	14615	+16
12		Williamson Co., Ill., Face sample:												
	538	(*a*) Sp. Gr. greater than 1.35....................	18.28	1.37	"	11731	14355		14531		14475		14667	
	468	(*b*) Sp. Gr. less than 1.35...	4.34	1.07	"	13970	14604	+249	14725	+194	14694	+219	14690	+23

The method of deriving a formula embodying the conditions prescribed under (*d*) would be as follows:

First, with reference to the subtraction of the heat due to the sulphur. It should be borne in mind that the purposes of this study are (1), to arrive at the actual weight of unit coal as represented by the expression 1.00 — (all non-coal constituents), and (2) to derive the actual heat per unit weight to be credited to this material, by dividing the indicated heat for this substance by the weight which produces it. Hence, for this particular purpose, the sulphur must be eliminated, both as to its heat value and as to its weight in the material whose value is sought for. This procedure may not suit the purpose of the engineer who has in mind only the available heat without reference to its source, but that is a matter quite apart from the facts which it is the purpose of this discussion to establish.

Second, the expression 5000 S has been used as indicating the heat due to the combustion of the sulphur, for the reason that the value 4050 S, as used in formula (*b*) represents the heat of combustion for pure sulphur, while the heat of combustion of sulphur in the form of pyrites, FeS_2, combines also the heat of formation of iron oxide, Fe_2O_3. It is the resultant value, therefore, of the several reactions involved that is desired.

According to the direct tests by Somermeier,[1] in the combustion of coal with known weight of iron pyrites, the indicated heat per gram of sulphur so combined is 4957 calories. In calculating heat values, the correction introduced for the combinations resulting from calorimeter reactions as compared with open-air combustion is 2042 calories per gram of pyritic sulphur; hence 4957 — 2042 or 2915 calories (5247 B. t. u.) represents the heat due to the burning of one gram of sulphur in pyritic form instead of 2250 calories (4050 B. t. u.), the amount which would be credited to sulphur in the free condition. A strict application of these values, therefore, would call for a correction of 5247 S, as representing the heat to be subtracted for the sulphur. This,

[1]Jour. Am. Chem. Soc. Vol. 26, p. 566.

however, would imply that all of the sulphur is in the pyritic form. Since a certain portion of the sulphur is always present in organic or other form of less heat-producing capacity, it is deemed more nearly correct to use an even factor of 5000 as representing the heat to be credited to unit amounts of the total sulphur present.

The factors for the divisor in the formula under (*d*) are derived as follows:

The atomic ratio of iron to sulphur in iron pyrites (FeS_2) is 56 : 64; that is, 7/8 of the total sulphur is the equivalent of the iron present as Fe.

The atomic ratio of the oxygen of the ash, combined as Fe_2O_3 to the total sulphur which it replaces is 48:128; that is, 3/8 of the total sulphur is the equivalent of the oxygen present in the ash, combined as Fe_2O_3, hence the ash as weighed may be corrected for the iron pyrites FeS_2 burned to Fe_2O_3, by subtracting from the ash 10/8 of the weight of the sulphur as determined. This remainder, therefore, is considered as the shaley and carbonate constituent upon which the 8 per cent of water of hydration, carbon dioxide, etc., are calculated. The expression for the total non-coal substance then becomes

Non-coal = Moisture + Ash as weighed + 5/8 S + .08 (Ash — 10/8 S).

Clearing of fractions and combining,

Non-coal = Moisture + 1.08 Ash + 21/40 S.

In this expression the factor 21/40 S can not be further simplified by making it 1/2 S, for the reason that our correction for sulphur is already too small by that part of the organic sulphur not covered by the addition to the ash value of 3/8 of the total sulphur indicated in the original formula. On the contrary, we shall be approaching nearer the truth by increasing slightly the sulphur correction, which may be done with convenience in calculating, by making this factor read 22/40 S or 1/2 S + 1/20 S.

Hence the simplification of the entire formula under (*d*) would be

B. t. u. or unit coal =

$$\frac{\text{Indicated B. t. u.} - 5000\ \text{S}}{1.00 - (\text{Moisture} + 1.08\ \text{Ash} + 1/2\ \text{S} + 1/20\ \text{S})}$$

Since the analytical values given in the table are based upon the coal as oven-dry, of course, the moisture factors in the above formula drop out, and would not enter into the calculations. In the table, for example, sample 1 has an indicated B. t. u. for the dry coal of 12 356. The calculations, therefore, for each column are

$$(a) = \frac{12356}{1.00 - .1166} = \ldots\ldots 13\,987$$

$$(b) = \frac{12356 - 4050\,(.0599)}{1.00 - (.1166 + .0599)} = \ldots\ldots 14\,709$$

$$(c) = \frac{12356}{1.00 - (.1166 + .0299)} = \ldots\ldots 14\,477$$

$$(d) = \frac{12356 - 5000\,(.0599)}{1.00 - [1.08(.1166) + .02995 + .00299]} = \ldots\ldots 14\,331$$

From an examination of this table it seems evident that the values in columns (*a*), (*b*), and (*c*) vary for each pair of samples more widely than we should expect, provided our calculation in these cases is based upon the actual coal; the variation, for example, reaching nearly 2 1/2 per cent in No. 9. That a hydration component is the disturbing factor seems evident from the wide variation in the ash of the two divisions of this sample (22.17 per cent to 4.22 per cent), while the sulphur values are sufficiently close to eliminate any variable due to that element. In column (*d*), however, it is to be noted that the introduction of an amount of hydration equal to 8 per cent of the pyrite-free ash brings the two heat values to a variation of only 41 B. t. u. or less than 1/3 of 1 per cent. The component calling for this correction, therefore, seems to be directly associated with the ash, since the variation in sulphur is too small to enter into the account. Equally striking evidence of the presence of such a component is seen in the samples numbered 7, 10, 11, and 12. Sample 8 is essentially the same as 7, and while there is not so close an agreement in this sample, still it must be recognized as confirmatory of the general proposition. If, for example, we admit a manipulation variant of 40 or 50 units, it is hardly to be expected that the other variables, such as the true amount of hydration or the exact character of the same, whether hydration of shale or carbonating of lime, may not carry with it an equal variable, so that in the present stage of our knowledge, it seems fair to consider even this variation quite within reasonable limits.

Another phase of these results is also to be noted. The agreement as to results just given above is seen to depend in large measure upon the correction of the high ashes in those samples referred to, by addition of a component which we have designated as hydration. Fortunately, the list of samples also includes coals high in sulphur, and this affords the necessary condition to show whether or not the sulphur enters into the proposition as a variable, and also what method of correction will most nearly neutralize its effect. Here, again, the close agreement, as in samples 1, 2, 4, 5, and 6, indicates that the method employed is correct in principle; that is, the heat value of the sulphur, taken as 5000 times the sulphur content, is subtracted from the indicated heat units, and the ash is restored as nearly as is conveniently possible, to include the sulphur as joined to the iron in its original or pyritic form. It is realized, as already indicated, that an error is inherent in this procedure, if that part of the sulphur is present as organically combined. Strictly considered, therefore, it should not be reckoned as pyritic sulphur. Test has been made, however, of introducing a further refinement into the calculation by separating the sulphur into the organic part and the inorganic, the amount of the latter being indicated by the content of iron present in the ash. The iron pyrites thus calculated, Table 2, on this iron basis has been made a part of the original non-coal substance. The 8 per cent of hydration, etc., has then been calculated to the ash as corrected for this amount of pyrites burned to oxide, and finally the organic sulphur has been added as a part of the non-coal matter. The indicated heat units were diminished by the total heat to be credited to the sulphur, taking account of its two forms as indicated in the formula for column (*e*), thus

$$(e) = \frac{\text{B. t. u.} - [5247 \times 8/7\ \text{Fe} + 4050 \times (\text{S} - 8/7\ \text{Fe})\ ]}{1.00 - [\text{Moisture} + \text{Ash} + 5/7\ \text{Fe} + .08\,(\text{Ash} - 10/7\ \text{Fe}) + (\text{S} - 7/8\,\text{Fe}]}$$

In this formula, the iron weighed as Fe_2O_3 has a ratio of oxygen to iron of 48 : 112 or 3/7. To restore it to an equivalent of FeS_2 which has a ratio of S (64) to Fe (56) or 8 : 7 would require the addition to the ash content of 5/7 of the iron as determined. Similarly 8/7 of the iron value represents the sulphur as originally joined to the iron in the pyritic form, and 10/7 of the iron represents the Fe_2O_3 as a component part of the ash as weighed.

Since the analytical values refer to the coal on the dry basis, the factor for moisture drops out of the formula. The results of this method of calculating are given for the first six samples in column (*e*) of Table 2, placed in comparison with column (*d*) repeated from the previous table. As may be readily seen, the relative values are in substantially the same agreement as before. This method involves the added requirement of an iron determination and does not altogether remove the uncertainty as to the form in which the combinations of sulphur occur. In the present state of our knowledge, as well as on the score of practicability, we seem to be justified in accepting the values and formula as given in column (*d*).

The arguments thus far brought forward to prove the correctness of the method for arriving at the real weight of non-coal substance are sufficiently conclusive for the twelve samples included in the table. How generally applicable this method will be for all types and all regions, remains for the subsequent part of this paper to discuss.

TABLE 2

COMPARATIVE VALUES OF "ACTUAL COAL"

Tab. No.	Lab. No.	Description of Sample	Oven-dry Coal				(d) Non-coal as 1.08 Ash + 22/40 S. Ref. to B. t. u. − 5000S.		(e) Non-coal as Ash, Water, Pyritic Sulphur, Organic Sulphur and 8% Ash as Corrected for Actual Fe_2O_3	
			Ash	Sulphur	Iron	B. t. u.		Diff.		Diff.
		Sangamon Co., Ill., Lump Coal:								
1	6130	(a) Untreated	11.66	5.99	3.38	12356	14331		14494	
2	6131	(b) Floated, Sp. Gr. less than 1.35	6.12	3.20	.65	13300	14340	+ 9	14536	−42
		Sangamon Co., Ill., Screenings:								
3	6122	(a) Untreated	18.21	4.25	2.37	11478	14442		14569	
4	6123	(b) Floated, Sp. Gr. less than 1.35	8.13	2.95	.70	13043	14392	−50	14567	− 2
		Williamson Co., Ill., Washed Nut:								
5	6290	(a) Untreated	12.83	1.85	1.09	12523	14603		14605	
6	6121	(b) Floated, Sp. Gr. less than 1.35	4.01	1.39	.54	13929	14602	− 1	14659	+54
		LaSalle Co., Ill., Washed Screenings:								
7	6129	(a) Untreated	10.05	3.43	2.32	12885	14566		14620	
8	6128	(b) Floated, Sp. Gr. less than 1.35	3.94	2.33	1.29	13922	14615	+49	14680	+60
		Vigo Co., Ind., Nut:								
9	6132	(a) Untreated	16.84	7.62	5.17	11790	14698		14779	
10	6133	(b) Floated, Sp. Gr. less than 1.35	4.27	3.08	1.06	13870	14638	−60	14783	+ 4
		Sullivan Co., Ind., Lump:								
11	6135	(a) Untreated	6.11	3.37	2.24	13664	14741		14833	
12	6134	(b) Floated, Sp. Gr. less than 1.35	2.53	1.29	.36	14259	14700	−41	14770	−63

As a possible source of variation, the different layers of the same seam were studied with a view to determining inherent variations in the stratification of the coal, which, by variations in sampling or mining, might enter into the case and to a certain extent, modify the fact of uniformity. Three mines were, therefore, sampled with reference to the top, middle, and bottom layers of coal, or with reference to certain zones or bands of coal that seemed to have a structure more or less characteristic and distinct from the other layers. These results are listed in the following table, the basis of comparison being the thermal units calculated to "unit coal," which in subsequent discussion, as already indicated, will be the term made use of in this paper for that coal free from ash, moisture, pyrites, and volatile inorganic matter, as calculated under column (*d*) in Tables 1 and 2.

Attention is called to the following points. In the Collinsville sample, the bands of division were approximately the upper 2 feet, the lower 2 feet, and the middle zone of about 4 feet. When referred to the "unit coal" basis, the upper and middle divisions are in close agreement. The lower layer is considerably higher. This fact would have a modifying influence on the entire face of the seam as is illustrated in No. 4, which is a calculated composite value based on the factors for samples No. 1, 2 and 3. No. 5 and 6 are samples taken from the entire face of the seam, and taken from a mine located not over 2 or 3 miles from the mine from which the first samples by layers were taken. It is evident that the values indicated for the separate layers are not variable to an extent which would noticeably change the ultimate value for the entire face. Moreover, in the process of mining, the output represents the face of the vein and not the various layers. However, the facts brought out in this comparison of the various strata are valuable as indicating certain variations in composition of the same seam which might result from changes in the relative thickness of certain bands. In the same region, or in the same vein, these possible variations due to this phase of the matter would seem to be practically negligible when we consider the regular output of the mine, since a mixture of the entire seam is inevitable, and these small variations of the layers would be very easily neutralized.

The same statement is applicable to the results as shown for the two additional sections similarly examined from Belleville

TABLE 3

VARIATIONS IN THE CALORIFIC VALUE OF THE "UNIT COAL" FOR DIFFERENT HORIZONTAL LAYERS OF THE SEAM

Tab. No.	Lab. No.	DESCRIPTION OF SAMPLE	OVEN-DRY COAL			Non-coal as 1.08 Ash + 22/40 S. Ref. to B. t. u. − 5000S.
			Ash	Sulphur	B. t. u.	
		COLLINSVILLE, ILLINOIS				
1	725*c*	Top 23 in.	6.14	4.44	13505	14606
2	725*b*	Middle 48 in.	12.02	3.84	12618	14634
3	725*a*	Bottom 22 in.	14.86	7.52	12297	14936
4	725	Calculated for entire face 93 in.	11.22	4.85	12762	14694
5	723	Sample taken from entire face.	12.23	4.37	12604	14675
6	724	Sample taken from entire face.	9.69	3.33	12982	14613
		BELLEVILLE, ILLINOIS				
1	1000	Top 4 in.	6.75	3.35	13629	14814
2	999	¼ in.; 2 in. from the top.	2.09	2.66	14255	14667
3	995	Entire face, 76–½ in.	12.47	4.19	12587	14694
		DUQUOIN, ILLINOIS				
1	422	Top 30 in.	6.13	.76	13573	14560
2	421	Bottom 69 in.	14.71	.98	12181	14516
3	....	Entire face. 99 in.	12.11	.91	12603	14531

and Duquoin. The agreement is even more marked than in the case of the Collinsville seam.

Notwithstanding these evidences of uniformity, the fact should not be lost sight of that these results have a special value in that they show at a glance the necessity of care in taking face samples, to see that the cut is made equally and from the entire working face of the seam. It is evident also that lump or hand samples which are frequently taken for analysis are not only of little value but are as a rule positively misleading, and the error is quite as likely to be of a minus as of a plus character.

IV. Ash Composition

Notwithstanding the very satisfactory indication of the adaptability of the proposed formula for arriving at the unit coal values, as shown by the foregoing Tables 1 and 2, the question still remains as to whether the samples chosen are sufficiently typical to represent all the varieties of composition so far as the ash or inorganic content is concerned. Under this division of the subject, therefore, is taken up a study of this phase of the matter. As a first step, it was deemed necessary to make an analysis of the ash of the coals selected for use in the above tables. For example, the somewhat arbitrary factor, 8 per cent, has been adopted as covering a constant amount of volatile inorganic constituent to be reckoned with the total ash. It may make an appreciable difference whether this component is present as water of hydration, as in a clay or shale, or combined with lime as carbon dioxide. If in the latter combination, the amount of lime present would be an indication of that fact, while the amount of alumina present might serve to indicate the likelihood of this percentage being represented by hydration of shale or clay. An analysis of the ash of the 12 samples as listed in Table 2 is given in Table 4.

In this table, attention is first called to the fact that, with the exception of sample 3, the amount of lime is quite uniform. Here the lime approximates 12 per cent. By reference to the column for alumina, which might be taken as an indication of the clayey matter present, a very fair uniformity also exists, with the possible exception of sample 11, where the aluminium content is relatively low. Now, turning to Table 2 for an indication of a variation in the calculated values for unit coal, it does not seem that these variations in samples No. 3 and No. 11 have entered into the case in an appreciable degree.

Thus far it might be safe to conclude, that the adoption of the 8 per cent constant, as representing the volatile matter of the ash, is applicable. However, if in this group we have a variation in the lime content from 2 to 12 per cent, as in samples 7 and 3, have we any evidence that it stops there? Similarly,

TABLE 4

Ash Composition of Coals of Table 2

Tab. No.	Lab. No.	Description	Ash in Dry Coal %	Analysis of Ash Per Cent				
				SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	6130	Sangamon Co., Ill., Lump.	11.66	33.1	42.5	17.9	5.6	0.9
2	6131	Sangamon Co., Ill., Lump.	6.12	54.2	16.4	24.2	4.1	1.2
3	6122	Sangamon Co., Ill., Screenings....................	18.21	49.2	20.7	17.1	11.9	1.1
4	6123	Sangamon Co., Ill., Screenings....................	8.13	55.9	13.0	23.6	6.7	0.8
5	6290	Williamson Co., Ill., Washed Nut.................	12.83	54.1	12.1	23.8	6.7	1.2
6	6121	Williamson Co., Ill., Washed Nut.................	4.01	51.7	19.3	24.6	2.4	1.0
7	6129	La Salle Co., Ill., Washed Screenings.............	10.05	40.3	34.0	22.8	2.0	0.9
8	6128	La Salle Co., Ill., Washed Screenings.............	3.94	....	....	....	....	..
9	6132	Vigo Co., Ind., Nut.......	16.84	32.9	43.8	20.5	2.9	0.9
10	6133	Vigo Co., Ind., Nut.......	4.27	35.1	35.6	25.3	2.3	0.6
11	6135	Sullivan Co., Ind., Lump..	6.11	27.1	52.3	14.1	4.4	1.2
12	6134	Sullivan Co., Ind., Lump..	2.53	45.8	20.2	28.3	5.4	0.0

if the alumina may drop from 25 per cent (No. 10) to 14 per cent (No. 11), can we conclude that these numbers represent the limits of variation, and, if not, will greater variations in these factors cause a disturbance in the factor chosen to represent the volatile matter present?

In extending our study over a wider range of ash analysis, we soon come upon cases where much higher percentages of lime are in evidence. In view of this fact, it was considered worth while to estimate also the carbon dioxide and the chlorine. The carbon dioxide would be a more direct index of volatile loss of ash than the content of lime, since the latter might be combined in other than carbonate form. Chlorine, if present in any form, would be volatile, depending on the temperature made use of. Table 5 is given as illustrating the extremes to which lime as calcium carbonate, and alumina combined as clayey matter may be met, at least in the ash from Illinois coals.

TABLE 5

ASH COMPOSITION OF COALS WITH HIGH PERCENTAGE OF LIME

Tab. No.	Lab. No.	DESCRIPTION	In per cent of Dry Coal			ANALYSIS OF ASH				
			Ash	CO_2	Cl	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	734	Grundy Co., Ill.	5.82	.88	none	22.8	32.4	10.2	34.0	0.7
2	1095	Saline Co., Ill.	11.49	1.22	.04	32.7	33.0	9.0	25.3	0.8
3	1178	Clinton Co., Ill.	15.56	2.48	.10	39.0	22.4	6.3	31.7	0.7
4	1403	Peoria Co., Ill.	15.46	2.48	none	25.7	12.9	6.8	54.5	1.5

It might be argued from the results in Table 5, that whereas the lime content is high, the alumina is low, and there is, therefore, a compensation which would still furnish evidence that the 8 per cent constant for the inorganic volatile matter would be applicable. However, to test the matter, it was deemed advisable to subject these samples to the floating test as already indicated, giving as a result two divisions of each sample, one with an abnormally low ash, the other with an abnormally high ash; the latter division in each case still further accentuating the lime factor. In consequence of this division, the analysis of the eight resulting samples together with the calorific values is presented in Table 6. Columns (*a*) and (*d*) only are given in order that a comparison may be made between the ash values for "ash and water-free" or "pure coal" with the "unit coal" values as derived by the formula already made use of on page 14.

From the calculations under column (*a*) and column (*d*), it is evident that the wide discrepancies under column (*a*) are due to a failure to take into consideration those mineral constituents of the coal which properly belong to the ash. This is the fuel unit designated the "ash and water-free," combustible or "pure coal" basis adopted by engineers. Under column (*d*), the

TABLE 6

Proximate Analysis with Calorific Values for Float and Sink Coal with High Percentages of Lime in the Ash

Tab. No.	Lab. No.	Description	In per cent of Dry Coal: Ash	Sul.	B. t. u.	Heat Value of "Actual Coal" as Calculated by Different Methods: (*a*) "Pure Coal" Basis $\frac{\text{B. t. u.}}{1.00 - \text{Ash}}$	Diff.	(*d*) "Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{S.}}{1.00 - (1.08\text{Ash} + {}^{22}/_{40}\text{S.})}$	Diff.
1	734	Float, Grundy Co.	4.57	1.44	13475	14120		14217	
2	734	Sink, Grundy Co.	21.99	5.00	10733	13760		14262	
							−360		+45
3	1095	Float, Saline Co..	6.42	2.65	13663	14600		14768	
4	1095	Sink, Saline Co...	19.94	7.01	11122	13902		14906	
							−698		+138
5	1178	Float, Clinton Co.	8.54	1.96	12634	13813		13975	
6	1178	Sink, Clinton Co..	31.90	3.75	8856	13004		13654	
							−809		−321
7	1403	Float, Peoria Co.	10.37	2.39	12796	14276		14489	
8	1403	Sink, Peoria Co..	34.24	4.71	9216	14014		14859	
							−262		+370

unit coal values come very much closer together, but are not in such satisfactory agreement as was the case with the coals in Table 2, having a low lime content in the ash. It is evident, therefore, that in these two extreme divisions which have been made by the process of floating out to get the lighter and sinking the heavier ash coal, the inorganic volatile matter must be accounted for in some further correction than would be included in the 8 per cent adopted in calculation for Table 2. It is evident in this set of samples, that we have accentuated in an extreme manner the effect of a high ratio of carbonate of lime, bringing this constituent up to 16.67 per cent of the total coal in No. 5 of the table, and to 11.99 per cent in No. 6. While these percentages are abnormal, they serve well the purpose of indicating the effect upon the proposed formula for arriving at unit coal values. The first question which presents itself, therefore, is whether we should not correct our ash factor, not by an 8 per cent addition alone, but by adding directly to the ash as weighed, the amount of carbon dioxide present, on the assumption that all of the calcium carbonate would be decomposed, setting free the CO_2. This involves another hypothesis, namely, that in the ordinary determination of ash, the calcium carbonate present is completely decomposed. To test this point, the four samples, subdivided into pairs of low and high ash each, were subjected first to the ordinary ash determination as directed by the Committee of the American Chemical Society on standard methods for coal analysis. No important modification of this method was employed. After complete burning off of the carbon in a porcelain crucible over a Bunsen lamp, a blast lamp, driven at moderate intensity, was applied for 30 to 40 minutes. The results are listed in Table 7, in the first column for ash percentages, marked (*a*). In the column marked (*b*), the method employed made use of a platinum crucible and after burning off the carbon, an intense heat was applied by means of the blast lamp, continuing the blasting to constant weight. As will be seen from these results, a very wide difference may be made in the seemingly simple matter of determining the ash. Evidently under column (*a*) only a part of the calcium carbonate has been decomposed in the "sink" samples.

In this table, therefore, we have a striking illustration of the variations that may enter into the ash determination. The evidence of a variable element indicated its presence in a very marked manner in the process of obtaining the values for column (*a*). It was found almost impossible to secure duplicate results, the values sometimes varying in the two portions run in parallel by as much as 1.00 per cent. This evidence of a high content of calcium carbonate and its effect on the accuracy of the ash deter-

TABLE 7

VARIATIONS IN ASH VALUES WHERE CALCIUM CARBONATE IS A CONSTITUENT OF THE COAL

Tab. No.	Lab. No.	DESCRIPTION	(a) Ash as Determined by Usual Method	(b) Ash as Determined by Blasting to Constant Wght and Fusion	Difference in per cent of Dry Coal
1	734	Float, Grundy Co., Ill .	4.57	3.54	1.03
2	734	Sink, Grundy Co., Ill. . .	21.99	16.85	5.14
3	1095	Float, Saline Co., Ill. . . .	6.42	5.96	0.46
4	1095	Sink, Saline Co., Ill.	19.94	18.59	1.35
5	1178	Float, Clinton Co., Ill. . .	8.54	7.23	1.31
6	1178	Sink, Clinton Co., Ill. . . .	31.90	26.88	5.02
7	1403	Float, Peoria Co., Ill. . .	10.37	9.08	1.29
8	1403	Sink, Peoria Co., Ill. . . .	34.24	22.93	11.31

mination is of far-reaching importance. It affects in a very material manner any method of reference to a unit of combustible, especially such as is made use of by the engineering profession under the designation of "ash and moisture-free" material. It also seriously affects those results in a coal analysis which are obtained indirectly by difference. For example, the value for fixed carbon is thus estimated. Any error in the ash determination is therefore loaded upon this constituent. An equally erroneous feature accompanies the ultimate analysis where the total carbon is measured as CO_2. The carbon dioxide combined with the calcium oxide in the coal is thus made to appear in the final result as augmenting the value for total carbon. But it is not the purpose here to discuss the effect of this possible source of error. The immediate problem in hand is to arrive at the actual non-coal or inorganic substance as an essential factor in calculating the values for unit coal. The obvious suggestion, therefore, would be to make a determination of all possible volatile constituents, especially the CO_2 and Cl and augment the ash values found at the higher temperature by these percentages. Such an analysis was made, as shown in Table 8. A complete analysis was also made showing all the mineral constituents, so that any bearing these factors might have, could be studied simultaneously with the question of the true ash or inorganic matter.

In considering the probable reactions of the ash at a fusion temperature, it would be conceded at once that all of the CO_2 would be driven off. This, therefore, would be the first increment to add to the ash as above determined. Similarly, the chlorine present would be driven off. Evidently, in these particular samples, the larger portion of the chlorine is combined as $CaCl_2$, which was not washed out of the texture of the coal after being subjected to the floating process in a $CaCl_2$ solution. But whether joined as NaCl or $CaCl_2$, it is probable that the ultimate result is the formation of silicates of sodium and calcium with liberation of chlorine. Hence it seems proper to add a second increment to the ash values, that of the chlorine percentages. When we come to a disposition of the SO_3 value, the case is not so clear. Ordinarily, it should be noted, the amount of sulphate present in a coal is so small as to be negligible, but it so happens that the samples selected for this particular series had been in laboratory storage for over a year, with the result, that when the ultimate constituents were all sought out, quite an appreciable amount of sulphate of iron had formed. Now the decomposition of this material is easily effected at a temperature above 300°. Hence the indication would seem to be that a further correction for the ash content should be made by adding the percentage found for this constituent. However, it should be borne in mind that calcium carbonate is present in sufficient quantity to take care of this SO_3 by formation of $CaSO_4 + CO_2$. By testing artificial mixtures of calcium carbonate and ferrous sulphate, with and without the addition of organic matter, the residual fusion showed sufficient sulphate remaining as $CaSO_4$ to warrant the conclusion that no correction should be made for the SO_3 found to be present in the original coal.

In view of these facts, therefore, the calculation for the unit

TABLE 8—Ash Composition—In per cent of Dry Coal

Tab. No.	Lab. No.	Description	Ash by Blasting to Constant Weight and Fusion in Pt. Cruc.	SiO_2	Fe_2O_3 Al_2O_3	CaO MgO	Na	Cl	SO_3	CO_2	Total S	B. t. u.
1	734	Float..........	3.54	.98	1.71	.85	.12	1.00	.43	.10	1.44	13475
2	734	Sink...........	16.85	2.44	7.91	6.50	.31	1.15	1.05	3.68	5.00	10733
3	1095	Float..........	5.96	2.93	2.63	.40	.07	.17	.22	.13	2.65	13663
4	1095	Sink...........	18.59	5.23	9.48	3.88	....	.31	.81	2.38	7.01	11122
5	1178	Float..........	7.23	3.33	3.02	.88	.23	1.41	.20	.21	1.96	12634
6	1178	Sink...........	26.88	9.03	9.49	8.36	.27	1.20	.56	5.27	3.75	8856
7	1403	Float..........	9.08	5.46	2.33	1.29	.22	1.07	.23	.31	2.39	12796
8	1403	Sink...........	22.93	5.64	7.09	10.20	.19	1.17	.99	7.35	4.71	9216

TABLE 9—"Unit Coal" in Samples with High Calcium Carbonate

Tab. No.	Lab. No.	Description	In Per Cent of Dry Coal				"Pure Coal" $\frac{B.t.u.}{1.00 - Ash}$		"Unit Coal" $\frac{B.t.u. - 5000S}{1.00 - (1.08 Ash (corr.) + {}^{22}/_{40} S.)}$	
			Ash as Determined by High Fusion to Constant Weight	CO_2	Cl	B. t. u.		Diff.		Diff.
1	734	Float.........	3.54	.10	1.00	13475	13969		14219	
2	734	Sink..........	16.85	3.68	1.15	10733	12908	−1061	14214	− 5
3	1095	Float.........	5.96	.13	.17	13663	14528		14742	
4	1095	Sink..........	18.59	2.38	.31	11122	13662	− 866	14736	− 6
5	1178	Float.........	7.23	.21	1.41	12634	13618		14030	
6	1178	Sink..........	26.88	5.27	1.20	8856	12111	−1507	14009	− 21
7	1403	Float.........	9.08	.37	1.07	12796	14073		14508	
8	1403	Sink..........	22.93	7.35	1.17	9216	11941	−2132	14172	−336

coal values on these samples was based on an ash content in which the ash as weighed had been subjected to a very high temperature in a platinum crucible, and continued until a constant weight was secured, and the ash fused; to this was added the CO_2 present in the dry coal, and also the factor for chlorine. The formula already given, therefore, was simply modified by the above conditions, and would be expressed as follows:

$$\text{Unit Coal} = \frac{\text{Indicated B. t. u.} - 5000\ S}{1.00 - [(\text{Ash} + CO_2 + Cl) \times 1.08 + 22/40\ S]}$$

The results of this calculation are given in Table 9, with a comparison wherein the values are calculated to "pure coal" or the "ash and water-free" basis and to the "unit coal" with the ash corrected for the CO_2 and Cl present.

Concerning these results, the proposed correction of the ash by addition of the CO_2 and Cl would seem to meet the conditions as indicated by the close agreement of the "unit coal" values. The last sample, No. 8 of the table, is not in so good agreement as could be wished. The only explanation to be suggested at the present time is that the very high per cent of calcium carbonate, 16.67 per cent, would seem to require that a correction be made in the calorimetric value to allow for the heat of decomposition required to separate that amount of calcium carbonate into its constituent parts. This would mean that 786.6 × 16.67 per cent or 131 B. t. u. would represent the heat of dissociation for the calcium carbonate present. This amount, added to the indicated heat, would represent the total heat developed in the combustion as 9112 B. t. u. This amount introduced into the formula would show 14 383 B. t. u. as the unit coal value, or a difference from the low ash sample of 112 units instead of 336 as in the table. More study of this extreme type of coal must be made, and upon fresh samples with the sulphate constituent eliminated, before a final judgment can be formulated as to the adaptability of the formula to such cases. The remarkable conformity of the values in three of the four cases would seem to argue strongly in favor of the corrections for CO_2 and Cl as covering the case. In consideration of the facts set forth, therefore, in these last tables, it was deemed necessary to make an extended inspection of the coals of the State with special reference to their content of carbonate and chlorine. About sixty samples were selected and in addition to the usual ash determination, analysis

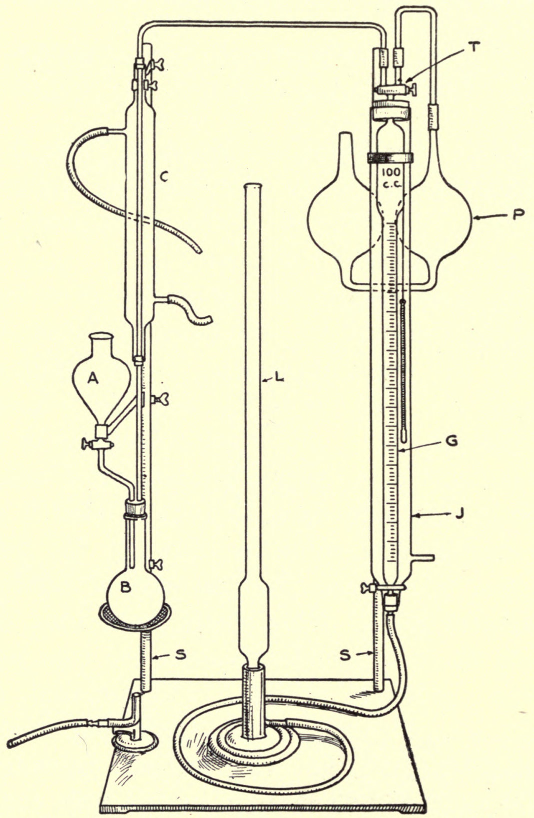

FIG. 1 APPARATUS FOR DETERMINING CO_2

was made of the ash constituent, namely, silicon, iron, alumina, lime, and magnesia. In addition, a determination was made of the chlorine and carbonate present. The chlorine was determined by digesting 2 grams of the pulverized coal on a steam bath with about 200 cc. of water, filtering, making up to 500 cc., and titrating an aliquot part with standard silver nitrate solution.

The carbonate was determined by weighing out 5 grams of coal and treating with acid in the apparatus designed for such work as shown in Fig. 1. This is an improved form of the apparatus described in Bulletin 7 of the Engineering Experiment Station, for the volumetric estimation of carbon dioxide, by absorbing the same in a pipette, as *P* of the figure, and measuring the contraction in the jacketed burette.

From the values thus obtained for these two constituents, it will be seen from the table that the high amounts of both are distributed quite irregularly throughout the State, and very frequently in a sufficiently high amount to make the introduction of their values into any careful analytical work on such coals an essential feature, if trustworthy results are to be forthcoming.

An answer is thus afforded, in such cases at least, to the query of the Committee of the American Chemical Society on Coal Analysis[1]: "Are carbonates likely to be present in the ash in such amount that heating over a blast lamp would lessen the weight appreciably?" An affirmative answer is also indicated in Table 7, where the weight of ash is lessened on blasting by 11.31 per cent of the coal, as in sample 8.

A further suggestion results from these frequent indications of carbon dioxide. The high carbonate content is accompanied by a high lime factor and the question at once occurs as to whether this factor for CO_2 might not serve as an index of fusibility of the ash quite as accurately as the content of sulphur, since high lime is as promotive of slagging as iron. Numerous tests on the fusibility of ash have confirmed this idea. It is hoped that this matter of the fusibility of coal ash may be taken up for further study in the near future.

[1]Jour. Am. Chem. Soc. Vol. 20, p. 284, 1898.

TABLE 10

Analysis of Coal Ash

(Including Values for CO_2 and Cl)

Tab. No.	Lab. No.	Description		Ash and Volatile Inorganic Matter Dry Coal Per Cent			Mineral Constituents of Ash as Obtained by High Fusion Per Cent				
		Location	Seam No.	Ash by Usual Method	CO_2	Cl	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	733	S. Wilmington, Grundy Co.	2	8.17	.15	None	28.8	41.1	22.5	7.0	.6
2	734	Coal City, Grundy Co.	2	5.82	.88	"	22.8	32.4	10.2	34.0	.7
3	1411	Hollis, Peoria Co.	2	10.90	.98	.27	33.3	41.8	10.2	16.6	.7
4	896	Spillerton, Williamson Co.	5	10.68	.70	.31	43.2	37.9	12.5	3.9	.5
5	1092	Equality, Gallatin Co.	5	10.85	.72	None	39.5	29.6	8.5	23.8	1.0
6	1094	Eldorado, Saline Co.	5	10.54	.26	.15	42.8	38.3	9.3	8.3	1.3
7	1095	Eldorado, Saline Co.	5	11.49	1.22	.04	32.7	33.0	9.0	25.3	.8
8	1110	Eldorado, Saline Co.	5	12.68	.51	.14	30.6	49.7	7.3	13.0	.8
9	1112	Harrisburg, Saline Co.	5	8.99	.11	None	48.7	26.1	22.5	3.2	1.2
10	1115	Ledford, Saline Co.	5	11.58	.34	"	40.0	26.4	21.8	9.3	1.1
11	1116	Ledford, Saline Co.	5	9.89	1.51	.05	29.4	20.0	20.3	26.5	2.0
12	540	Springfield, Sangamon Co.	5	10.76	.32	.08	40.5	37.0	8.2	11.8	.5
13	720	Lincoln, Sangamon Co.	5	13.81	.54	.32	35.1	22.4	10.2	30.8	1.5
14	740	Springfield, Sangamon Co.	5	12.75	.34	None	56.4	14.9	18.4	9.1	1.2
15	741	Springfield, Sangamon Co.	5	12.47	.85	.24	43.3	24.1	9.0	19.9	1.2
16	1403	Bartonville, Peoria Co.	5	15.46	2.48	None	25.7	12.9	6.8	54.5	1.3
17	1404	Canton, Fulton Co.	5	12.52	1.30	"	43.9	20.1	12.3	22.4	1.3
18	1407	Edwards Sta., Peoria Co.	5	16.25	2.15	.03	33.1	30.6	3.2	31.1	.8
19	1410	Maxwell, Peoria Co.	5	14.78	1.57	None	34.3	24.8	8.1	31.3	.7
20	1412	E. Peoria, Tazewell Co.	5	.....	.61	.19	45.0	26.3	11.6	16.1	1.0
21	1413	Pekin, Tazewell Co.	5	.....	1.36	None	43.0	17.7	6.6	31.6	1.0

TABLE 10

Analysis of Coal Ash

(Including Values for CO_2 and Cl)—(*Continued*)

Tab No.	Lab. No.	Description: Location	Description: Seam No.	Ash and Volatile Inorganic Matter, Dry Coal, Per Cent: Ash by Usual Method	CO_2	Cl	Mineral Constituents of Ash as Obtained by High Fusion, Per Cent: SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
22	557	Westville, Vermilion Co.	6	9.15	1.08	.15	47.9	26.9	18.5	5.6	1.1
23	558	Westville, Vermilion Co.	6	8.03	.47	.15	52.9	23.8	5.8	17.1	.3
24	722	Thayer, Sangamon Co.	6	11.04	.19	.23	44.0	32.0	13.2	9.8	1.0
25	725*a*	Collinsville, St. Clair Co.	6	11.22	.70	None	50.9	17.3	19.5	11.8	.6
26	725*b*	Collinsville, St. Clair Co.	6	.....	.72	"	48.2	18.2	21.3	11.0	1.3
27	725*c*	Collinsville, St. Clair Co.	6	.....	.37	"	33.6	27.2	11.4	16.8	1.2
28	735	Mt. Olive, Macoupin Co.	6	10.86	.36	.16	40.7	32.5	17.0	9.8	.8
29	736	Mt. Olive, Macoupin Co.	6	11.40	.13	.22	49.1	32.2	13.5	4.5	1.4
30	991	Belleville, St. Clair Co.	6	15.80	.....	....	44.8	20.3	18.6	16.4	1.5
31	996	Germantown, Clinton Co.	6	10.47	.44	.23	38.8	27.5	19.4	13.2	1.1
32	1001	Lebanon, St. Clair Co.	6	12.53	.65	.12	52.9	16.7	17.3	11.8	1.3
33	1002	O'Fallon, St. Clair Co.	6	13.43	.50	.16	44.3	28.4	13.2	11.5	1.3
34	1003	S. W. of O'Fallon, St. Clair Co.	6	12.94	.76	None	44.4	19.3	20.8	16.1	1.1
35	1117	Donkville, Madison Co.	6	10.59	.64	None	40.8	27.4	13.2	16.9	1.6
36	1118	Troy, Madison Co.	6	13.65	.55	.05	44.8	19.2	21.2	11.2	1.1
37	1119	Maryville, Madison Co.	6	11.72	.71	.09	45.6	27.0	5.8	20.8	.8
38	1176	Breese, Clinton Co.	6	13.59	.40	.33	55.5	21.4	5.9	16.4	.8
39	1178	Trenton, Clinton Co.	6	15.56	2.48	.10	39.0	22.4	6.3	31.7	.7
40	419	Zeigler, Franklin Co.	7	10.11	.37	.50	59.0	3.1	31.0	5.6	1.3
41	420	Zeigler, Franklin Co.	7	7.53	.21	.55	54.3	9.0	29.1	6.3	1.3
42	421	DuQuoin, Perry Co.	7	14.71	.65	.42	55.2	8.3	26.6	7.3	1.3

TABLE 10

Analysis of Coal Ash

(Including Values for CO_2 and Cl)—(*Concluded*)

Tab. No.	Lab. No.	Description		Ash and Volatile Inorganic Matter Dry Coal Per Cent			Mineral Constituents of Ash as Obtained by High Fusion Per Cent				
		Location	Seam No.	Ash by Usual Method	CO_2	Cl	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
43	422	DuQuoin, Perry Co.	7	.....	.28	.47	53.9	7.8	28.0	6.7	1.0
44	459	Herrin, Williamson Co.	7	8.48	.12	.13	59.9	8.1	29.4	1.9	1.0
45	460	Herrin, Williamson Co.	7	10.13	.47	.12	56.1	8.1	27.2	5.4	.9
46	461	Sesser, Franklin Co.	7	.....	.28	.56	51.4	10.2	31.5	5.7	1.1
47	462	Marion, Williamson Co.	7	7.66	.14	None	50.1	20.0	26.2	2.9	.8
48	1088	Herrin, Williamson Co.	7	10.65	.35	"	46.2	31.5	9.0	12.8	.6
49	1120	Galatia, Saline Co.	7	.....	1.20	.07	45.4	25.3	16.9	11.6	.8
50	1121	Norris City, White Co.	7	11.50	.41	.20	41.4	34.6	10.6	12.1	1.2
51	....	Taylorville, Scrgs. Comp.	...	.....	....	....	45.1	21.5	19.8	12.4	1.2
52	6121	Marion, W. Nut.	7	.....	....	....	51.7	19.3	24.6	2.4	1.0
53	6122	Lincoln, scrgs.	5	.....	....	....	49.2	20.7	17.1	11.9	1.1
54	6123	Lincoln, scrgs.	5	.....	....	....	55.9	13.0	23.6	6.7	.8
55	6129	La Salle, W. scrgs.	5	.....	....	....	40.3	34.0	22.8	2.0	.9
56	6130	Pawnee, Lump	6	.....	....	....	33.1	42.5	17.9	5.6	.9
57	6131	Pawnee, Lump	6	.....	....	....	54.2	16.4	24.2	4.1	1.2
58	6132	Vigo County, Indiana	...	.....	....	....	32.9	43.8	20.5	2.9	.9
59	6133	Vigo County, Indiana	...	.....	....	....	35.1	35.6	25.3	2.3	.8
60	6134	Sullivan Co., Indiana	...	.....	....	....	45.8	20.2	28.3	5.4	.0
61	6135	Sullivan Co., Indiana	...	.....	....	....	27.1	52.3	14.1	4.4	1.2
62	6290	Marion, Williamson Co., Ill.	7	.....	....	....	54.1	12.1	23.8	6.7	1.2

V. Summary

The principles developed by the foregoing discussion may be stated as follows:

1. Ordinarily the total inorganic or non-coal constituent is expressed by the formula

$$\text{Total Inorganic Matter} = M + 1.08\,A + 22/40\,S$$

in which M = moisture, A = ash, and S = sulphur. The formula for calculating the heat value for unit coal, therefore, basing the calculation upon wet coal values, would be

$$\text{B. t. u. of Unit Coal} = \frac{\text{Indicated (wet) B. t. u.} - 5000\,S}{1.00 - (M + 1.08\,A + 22/40\,S)}$$

and for dry coal:

$$\text{B. t. u. of Unit Coal} = \frac{\text{Indicated (dry) B. t. u.} - 5000\,S}{1.00 - (1.08\,A + 22/40\,S)}$$

2. A coal of unknown character as to its carbonate content should be subjected to a carbonate determination readily effected by liberating the CO_2 with acid and measuring the same by weight or volume. Where carbonates are found to exist in any considerable quantity, say over 0.3 per cent CO_2, the ash determination should be made by blasting in a platinum crucible to constant weight, and the ash as thus determined corrected by adding the weight found for CO_2. Further, since this method of deriving the weight of ash will drive off the chlorine present, this constituent should also be determined and the amount as Cl added to the weight of ash.

It has been possible to apply the foregoing principles to a large number of analyses which have been made in this laboratory. Some from the same mine extending over a considerable period of time afford a good opportunity of verifying the constancy of the unit coal values from the same mine. Others from the same geological seam, extending over a considerable area, as well as those from neighboring mines, serve to demonstrate a positive relationship and, so far as they are available, establish the unit values for their respective regions. An extension of these data has been prepared and arranged in tables following this discussion. In addition to the results obtained in our own laboratory, the various coal values as published by the Ohio State Survey[1] (Appendix A) and the United States Geological Survey[2] (Appendix B) have been calculated to unit values by the formula already developed and indicated at the head of the column for "Unit Coal." A most interesting study is there made possible of the constancy of values for a given type of coal or for a given region.

The application which the facts of the tables may be made to serve are many and of far-reaching importance. The real value and the extent of this service hinge upon the accuracy with which we may differentiate between the actual or unit coal and the true ash content. It is believed that the methods and formulas herein proposed are accurate within the limits of variation, inherent in the composition of the unit substance itself, and in the manipulation and methods of analysis employed. Concerning this latter point, it is obviously impossible in applying the calculations to analytical values already published, to take account of errors in ash determination, due for example to the presence of carbonate of lime. Some of the discrepancies in unit values, therefore, may be due to this fact. Moreover, some of the samples grouped by counties may be from different seams and hence show a difference in their unit values. It has not been practicable to give more detail of location or deposit than is contained in the tables, but the facts thus presented seem to have sufficient value to warrant their publication in this form.

An inspection of Table 10, (p. 31), shows a number of coals with over 2 per cent of CO_2 present. This represents approximately 5 per cent of calcium carbonate. In the Mahler type of calorimeter, this material is decomposed, representing a loss of heat amounting to about 40 B. t. u. for each 5 per cent of calcium carbonate present. A question is therefore raised as to the desirability of correcting heat values obtained by that instrument, to take account of this reaction in the calorimeter.

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[1]Geological Survey of Ohio, Fourth Series, Bul. No. 9, 1908.

[2]United States Geological Survey, Bulletins No. 261, No. 290, and No. 332.

VI. Conclusions

1. The actual or unit coal of a given deposit or region is remarkably uniform in composition, as shown by the constancy of heat values, when calculated to such unit substance.

2. The true percentage content of the actual or unit coal hinges upon the correct determination of the inorganic constituents of the coal. The present methods of analysis fail to take account of such constituents as the hydration of the shaley or clayey portions of the ash or the carbon dioxide content of earthy carbonates. The presence of chlorine compounds may sometimes be sufficient in amount to require consideration and estimation.

3. Coal with an ash of unknown composition should be examined for carbonates and chlorides. If the combined amount of these constituents approximates 0.5 per cent, the ash determination should be made at a temperature sufficiently high for their complete elimination, and a correction made for the ash value thus obtained by adding the amount of CO_2 and Cl found.

4. Apart from the corrections which may be called for on account of the presence of CO_2 or Cl, a factor for hydration is necessary, amounting to 8 per cent of the ash as determined, minus the ferric oxide resulting from the decomposition of the iron pyrites.

5. The assembling of the corrections indicated may be embodied in a simple formula, easy of application, and under two headings as follows:

For coals free from carbonates and chlorides

$$\text{Unit B. t. u.} = \frac{\text{Indicated Dry B. t. u.} - 5000\ S}{1.00 - (1.08\ \text{Ash} + 22/40\ S)}$$

For coals with carbonates and chlorides

$$\text{Unit B. t. u.} = \frac{\text{Indicated Dry B. t. u.} - 5000\ S}{1.00 - [\ (\text{Ash at high temp.} + CO_2 + Cl)\ 1.08 + 22/40\ S.]}$$

VII. Tabulation of Calculated Values for Unit Coal

From the tables following, (Tables 11 to 19 inclusive), not only is there evidence of a constancy of values for a given area, but, conversely, a given type of fuel over widely separated areas has a value which varies between relatively narrow limits and may be made to serve as an index of the kind or type and probably the region from which the material comes. From an inspection of these and other data a tentative series of values defining the suggested limits for the generally recognized fuel types is given in Table 11.

TABLE 11

Classification of Fuel Types by Heat Values for Unit or Actual Organic Substance

Cellulose and wood	6500 to 7800
Peat	7800 to 11500
Lignite-brown	11500 to 12500
Lignite-black	12500 to 13500
Sub-bituminous Coal	13500 to 14200
Bituminous Coal (mid continental field)	14200 to 15000
Bituminous Coal (eastern field)	15000 to 16000
Semi-anthracite and Semi-bituminous	15500 to 16000
Anthracite	15000 to 15500

TABLE 12

COAL RESULTS

From Continuous Deliveries, September 1, 1907 to September 1, 1908.

Each Sample Represents 5 Cars or 250 Tons, and is a Composite of 5 Separate Samples.

Shipments all from the Same Mine, Christian Co., Ill.

Lab. No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$	Variation from Average B. t. u.
	Moisture	Ash	Sulphur	B. t. u.		
933	13.16	17.07	4.39	9665	14313	−160
934	10.89	17.34	4.87	10104	14564	+ 91
935	13.49	15.14	3.99	10082	14539	+ 66
936	13.76	16.26	4.01	9845	14507	+ 34
937	14.00	16.97	4.41	9680	14499	+ 26
938	12.55	17.40	4.19	9883	14576	+103
939	12.57	18.70	4.43	9709	14643	+170
940	12.99	16.25	4.10	9971	14533	+ 60
941	12.71	17.27	4.55	9871	14580	+107
942	12.18	18.53	5.35	9724	14577	+104
943	11.52	16.13	4.36	10211	14554	+ 81
944	12.21	15.31	4.32	10278	14608	+135
945	13.53	16.14	4.38	9824	14420	− 53
946	14.99	14.96	4.15	9885	14537	+ 64
947	15.07	15.09	4.27	9825	14501	+ 28
948	14.25	15.51	3.91	9896	14510	+ 37
949	12.98	15.25	3.70	10076	14437	− 36
957	13.17	16.40	4.16	9880	14472	− 1
990	13.03	18.05	4.39	9773	14683	+210
1024	14.59	16.20	4.18	9830	14664	+191
1025	13.38	17.51	4.19	9747	14580	+107
1026	14.28	16.31	4.71	9840	14558	+185
1027	13.84	16.56	4.23	9842	14602	+129
1071	13.88	16.06	4.51	9868	14543	+ 70
1072	13.66	16.31	4.46	9837	14505	+ 32
1073	12.99	15.71	4.15	10076	14563	+ 90
1074	12.43	17.95	4.66	9834	14631	+158
1075	12.70	17.01	4.12	9857	14478	− 5
1076	13.79	18.63	4.95	9497	14595	+122
1077	13.62	15.90	4.36	9935	14544	+ 71
1180	13.45	16.68	4.00	9801	14472	− 1
1181	13.17	17.95	4.85	9607	14457	− 16
1182	13.49	13.36	3.97	9964	14415	− 58
1183	12.16	19.20	5.01	9556	14462	− 11
1184	11.90	17.16	4.55	9925	14458	− 15
1185	12.97	16.63	4.60	9893	14522	+ 49
1186	13.73	16.66	4.34	9795	14536	+ 63
1187	13.80	16.10	4.27	9884	14550	+ 77
1188	14.28	15.84	4.54	9763	14424	− 49
1204	14.51	18.04	4.35	9464	14533	+ 60

TABLE 12

COAL RESULTS—(*Concluded*)

Lab. No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$	Variation from Average B. t. u.
	Moisture	Ash	Sulphur	B. t. u.		
1205	14.13	16.31	4.85	9746	14488	+ 15
1272	15.81	15.18	3.86	9650	14399	− 74
1273	15.21	14.45	4.04	9910	14498	+ 25
1274	15.40	16.08	5.03	9560	14440	− 33
1275	14.04	16.44	4.52	9694	14409	− 64
1276	14.35	18.13	4.62	9315	14299	−174
1326	14.81	16.56	4.22	9540	14354	−119
1327	13.46	17.87	4.65	9505	14335	−138
1328	13.56	17.53	4.67	9568	14373	−100
1329	14.98	14.37	3.90	9928	14451	− 22
1330	14.59	16.63	4.34	9614	14444	− 29
1331	14.10	17.42	4.82	9592	14511	+ 38
1332	13.13	16.12	4.58	9783	14272	−201
1447	13.28	17.10	4.19	9670	14346	−127
1448	12.62	18.18	4.46	9590	14344	−129
1449	13.31	18.15	4.50	9584	14485	+ 12
1450	13.21	16.16	4.21	9852	14385	− 88
1451	13.32	17.01	4.28	9656	14313	−160
1695	15.31	13.19	3.61	9999	14341	−132
1696	16.12	13.10	3.76	9890	14339	−134
1697	15.62	14.29	3.61	9782	14338	−135
1759	14.02	15.62	4.43	9817	14392	− 81
1760	13.83	16.54	4.49	9676	14354	−119
1789	13.49	19.41	4.07	9331	14416	− 57
1832	14.09	17.22	4.17	9605	14451	− 22
1833	13.56	17.07	3.93	9704	14439	− 34
1834	13.56	17.50	4.24	9590	14381	− 92
Av....	13.65	16.58	4.35	9779	14475	± 82

TABLE 13

COAL RESULTS

From Continuous Deliveries September 1, 1908, to May 1, 1909
Each Sample represents 300 Tons
Shipments all from the Same Mine, Vermilion Co., Ill.

Lab. No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ S}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ S.)}$	Variation from Average B. t. u.
	Moisture	Ash	Sulphur	B. t. u.		
1879	12.92	16.58	3.82	9992	14613	−143
1880	14.22	18.16	4.51	9540	14624	−132
1881	12.45	17.22	4.14	9950	14608	−148
1883	13.00	19.48	4.31	9501	14601	−155
1896	12.08	17.13	3.67	10160	14801	+ 45
1897	12.67	16.90	4.26	10062	14757	+ 1
1898	12.71	16.79	4.22	10071	14752	− 4
1899	12.36	18.80	5.17	9801	14794	+ 38
1900	12.36	16.53	5.07	10170	14800	+ 44
1902	12.70	15.20	3.89	10269	14655	−101
1903	12.65	15.27	3.78	10208	14567	−189
1905	12.38	18.00	4.59	9913	14747	− 9
1906	12.46	18.30	4.21	9787	14629	−127
1908	11.76	16.12	3.48	10402	14840	+ 84
1909	11.74	15.10	3.93	10440	14677	− 79
1911	12.34	16.19	4.23	10324	14903	+147
1912	12.59	18.25	4.10	9772	14620	−136
1919	16.76	16.68	3.70	9512	14760	+ 4
1920	16.92	18.20	3.83	9232	14745	− 11
1934	12.93	16.44	3.54	10200	14878	+122
1942	12.72	17.62	4.07	9949	14763	+ 7
1943	15.03	16.45	4.09	9846	14844	+ 88
1947	13.90	18.31	4.08	9689	14800	+ 44
1990	14.47	15.57	3.85	10021	14759	+ 3
1991	13.31	18.08	4.35	10020	15134	+378*
1987	12.80	14.51	3.64	10476	14805	+ 49
1988	12.68	14.54	3.80	10508	14840	+ 84
1993	13.19	17.33	4.16	9931	14777	+ 21
1994	13.31	18.44	4.15	9849	14947	+191
1996	11.85	20.36	5.47	9720	14958	+202
1997	12.05	20.83	4.13	9512	14728	− 28
2007	13.73	19.23	3.91	9527	14729	− 27
2008	13.53	18.60	4.33	9638	14720	− 36
2016	13.38	19.72	4.42	9583	14886	+130
2017	13.28	18.24	4.56	9797	14833	+ 77
2013	12.48	21.14	5.11	9348	14693	− 63
2014	12.89	18.78	3.78	9742	14880	+124
2029	14.24	19.64	4.47	9431	14829	+ 73
2030	15.90	16.35	3.75	9667	14724	− 32
2031	14.11	17.36	3.97	9677	14591	−165
2032	13.66	15.43	3.77	10173	14767	+ 11

*_Probably due to error in ash determination.

TABLE 13

COAL RESULTS—(*Concluded*)

Lab. No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$	Variation from Average B. t. u.
	Moisture	Ash	Sulphur	B. t. u.		
2057	13.61	15.71	4.13	10128	14775	+ 19
2071	12.16	18.31	3.98	9986	14856	+100
2072	12.22	18.93	3.93	9857	14821	+ 65
2073	13.10	20.38	3.99	9520	14864	+108
2074	12.47	19.37	4.04	9791	14892	+136
2106	13.31	17.49	4.03	9816	14660	− 96
2107	14.07	17.50	4.43	9742	14739	− 17
2108	13.12	17.25	4.41	9987	14837	+ 81
2145	12.81	16.82	3.98	10066	14764	+ 8
2146	13.97	15.64	4.76	9813	14632	−124
2147	13.19	17.68	4.21	9805	14668	− 68
2159	13.30	17.98	4.17	9831	14805	+ 49
2160	12.20	20.14	4.78	9628	14805	+ 49
2161	13.12	17.61	4.34	9900	14790	+ 34
2178	14.83	19.77	3.90	9319	14793	+ 37
2179	14.01	17.92	4.13	9858	14993	+237*
2180	13.03	19.92	4.11	9503	14710	− 46
2232	14.07	17.40	4.12	9815	14813	+ 57
2233	13.26	19.54	4.25	9381	14483	−273*
2234	12.26	18.90	3.95	9611	14446	−310*
2235	13.02	17.94	4.46	9706	14547	−209
2304	15.07	19.03	4.42	9346	14730	− 26
2305	14.22	16.93	4.81	9718	14614	−142
2324	15.16	16.98	3.72	9706	14771	+ 15
2325	15.33	16.60	3.77	9792	14849	+ 93
2326	11.99	19.10	4.13	9801	14735	− 21
2369	12.00	18.42	3.92	9900	14712	− 44
2370	14.29	18.74	4.63	9498	14727	− 29
2371	13.28	17.33	4.17	9897	14744	− 12
2416	13.55	18.55	4.48	9630	14706	− 50
Av....	13.30	17.79	4.18	9828	14756	± 86

* Probably due to error in ash determination.

TABLE 14

COAL RESULTS

Run-of-Mine Coal from Two Mines, Boulder Co., Colo.

No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$	Variation from Average B. t. u.
	Moisture	Ash	Sul.	B. t. u.		
13	19.59	8.38	.52	9349	13118	+120
15	20.18	8.15	.39	9362	13193	+195
19	20.26	6.85	.38	9434	13053	+ 55
20	19.64	6.83	.36	9519	13054	+ 56
22	19.49	7.23	.48	9580	13192	+194
24	19.43	5.77	.38	9625	12958	− 40
25	19.12	7.16	.42	9620	13164	+166
27	20.43	6.40	.36	9512	13102	+104
30	19.65	8.55	.41	9271	13048	+ 50
31	19.91	6.75	.38	9425	12958	− 40
35	20.32	7.85	.44	9431	13260	+262
37	19.71	4.88	.38	9779	13046	+ 48
5	20.23	5.81	.35	9373	12761	−237
7	19.73	5.08	.29	9598	12842	−156
8	19.64	5.97	.30	9497	12859	−139
9	19.83	5.54	.29	9573	12911	− 87
13	20.06	5.51	.33	9551	12917	− 81
18	20.08	4.82	.38	9632	12902	− 96
19	19.96	5.63	.30	9588	12972	− 26
34	19.99	6.55	.40	9441	12955	− 43
38	19.38	5.11	.27	9712	12939	− 59
42	19.96	6.95	.25	9422	12998	00
45	20.56	5.60	.26	9428	12853	−145
76	18.09	5.56	.41	9835	12907	− 91
Av......	19.80	6.37	.36	9523	12998	±104

TABLE 15

COAL RESULTS

Run-of-Mine Coal from One Mine, Las Animas Co., Colo.

No.	Analyses of Samples as Received				"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{S}}{1.00 - (1.08 \text{ Ash} + \frac{22}{40}\text{ S.})}$	Variation from Average B. t. u.
	Moisture	Ash	Sul.	B. t. u.		
2	2.25	9.72	.89	13309	15288	− 4
10	2.40	11.33	.68	13066	15334	+ 42
12	2.51	14.49	.68	12547	15359	+ 67
14	2.63	11.32	.61	13033	15332	+ 40
15	2.93	11.53	.61	13065	15465	+173
16	2.57	12.81	.60	12842	15386	+ 92
21	2.80	20.17	.65	11643	15468	+176
23	2.26	9.45	.60	13297	15214	− 78
25	2.43	14.86	.60	12572	15448	+156
33	2.02	11.14	.63	13025	15144	−148
37	2.95	13.01	.59	12532	15121	−171
41	3.65	12.22	.63	12584	15159	−133
44	2.48	12.77	.58	12722	15218	− 74
46	2.19	11.57	.61	12904	15150	−142
Av......	2.58	12.59	.64	12796	15292	±107

TABLE 16

Illinois "No. 2" Coal

Lab. No.	Locality	Total Moisture	Referred to Dry Coal			"Unit Coal" Basis
			Ash	Sul.	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\text{S.})}$
1764	Bureau Co.	15.61	9.59	4.29	13008	14657
1769	Bureau Co.	15.99	8.96	4.04	13191	14743
1860	Brown Co.	15.60	10.02	6.01	13099	14904
1869	Christian Co.	11.54	10.08	4.38	13148	14912
1811	Fulton Co.	15.37	7.55	3.67	13558	14888
1839	Green Co.	14.93	12.43	5.79	12581	14739
1840	Green Co.	15.04	12.38	6.03	12538	14687
733	Grundy Co.	14.69	8.17	3.62	13217	14616
1787	Grundy Co.	17.18	6.82	3.11	13450	14622
734	Grundy Co.	14.16	5.82	1.83	13436	14395
1861	Hancock Co.	13.48	6.88	4.29	13516	14744
1875	Jackson Co.	14.25	4.99	.79	14113	14943
1878	Jackson Co.	12.73	4.75	.71	14115	14902
1876	Jackson Co.	9.00	6.87	2.02	13799	14975
1765	La Salle Co.	14.03	9.77	3.36	13033	14686
1785	La Salle Co.	12.41	8.89	3.23	13329	14858
1768	LaSalle Co.	15.36	14.03	5.34	12241	14618
1775	Marshall Co.	14.60	7.29	1.90	13539	14761
1795	Marshall Co.	13.54	6.66	2.90	13743	14908
1831	McDonough Co.	16.42	8.18	3.23	13418	14829
1748	Mc Lean Co.	12.02	10.13	3.36	12980	14704
1857	Mercer Co.	17.56	11.58	5.47	12666	14669
1411	Peoria Co.	12.05	10.90	4.48	12866	14739
1802	Warren Co.	18.52	5.45	3.20	13650	14606
1793	Woodford Co.	16.18	8.33	3.55	13361	14802

TABLE 17

ILLINOIS "NO. 5" COAL FROM SOUTHERN PART OF STATE

Lab. No.	Locality	Total Moisture	Referred to Dry Coal			"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
			Ash	Sul.	B. t. u.	
1092	Gallatin Co.	4.47	10.85	3.72	13235	15133
1094	Saline Co.	6.03	10.54	3.12	13212	15024
1095	Saline Co.	4.89	11.49	4.16	12931	14916
1110	Saline Co.	4.34	12.68	6.12	12879	15157
1111	Saline Co.	6.64	9.21	2.35	13367	14927
1112	Saline Co.	6.10	8.99	3.52	13415	15019
1113	Saline Co.	5.97	7.62	2.30	13700	15011
1114	Saline Co.	4.43	9.04	2.47	13450	14993
1115	Saline Co.	6.04	11.58	3.26	12942	14911
1116	Saline Co.	6.13	9.89	2.37	13298	14973
896	Williamson Co.	6.29	10.68	3.86	13073	14930
1809	Williamson Co.	6.47	12.53	3.62	12853	15000

TABLE 18

ILLINOIS "NO. 5" COAL FROM CENTRAL PART OF STATE

Lab. No.	Locality	Total Moisture	Referred to Dry Coal			"Unit Coal" Basis
			Ash	Sul.	B. t. u.	B. t. u. − 5000 S / 1.00 − (1.08 Ash + $^{22}/_{40}$ S.)
1404	Fulton Co.	15.09	12.52	3.79	12450	14527
1807	Fulton Co.	15.03	12.98	2.95	12389	14510
1808	Fulton Co.	15.49	13.43	3.81	12364	14594
1856	Fulton Co.	15.44	12.22	4.17	12666	14740
1771	La Salle Co.	13.13	12.19	4.15	12544	14590
1788	Livingston Co.	12.73	12.15	3.67	12853	14929
1569*a*	Macon Co.	13.91	11.33	3.82	12549	14427
1874	Macon Co.	14.07	11.82	4.28	12545	14529
1749	Mc Lean Co.	12.56	14.06	4.74	12299	14672
1847	Mc Lean Co.	14.15	13.54	2.82	12485	14725
1848	Menard Co.	15.55	12.20	3.58	12590	14627
1403	Peoria Co.	14.29	15.46	3.16	12094	14635
1407	Peoria Co.	13.86	16.25	3.91	12044	14755
1408	Peoria Co.	13.91	15.23	3.39	12189	14713
1409	Peoria Co.	13.45	16.66	3.58	12014	14786
1410	Peoria Co.	14.73	14.78	3.97	12257	14730
540	Sangamon Co.	13.56	10.76	4.78	12749	14589
721	Sangamon Co.	14.39	13.64	4.61	12304	14593
740	Sangamon Co.	14.30	12.75	4.11	12369	14468
741	Sangamon Co.	13.13	12.47	4.28	12416	14495
1794	Sangamon Co.	13.69	14.26	3.88	12133	14477
1761	Sangamon Co.	14.61	12.48	4.55	12364	14444
1762	Sangamon Co.	14.56	12.85	4.54	12281	14415
1766	Sangamon Co.	15.42	14.73	4.19	12082	14515
1767	Sangamon Co.	15.53	12.68	3.83	12340	14427
1770	Sangamon Co.	14.89	11.32	4.79	12663	14591
1772	Sangamon Co.	14.00	12.83	4.06	12358	14486
1773	Sangamon Co.	14.44	11.71	4.85	12477	14447
1774	Sangamon Co.	14.41	11.80	5.09	12550	14557
1786	Sangamon Co.	14.18	14.67	5.00	12115	14574
1790	Sangamon Co.	16.41	10.69	3.65	12685	14477
1791	Sangamon Co.	15.44	12.91	4.01	12301	14430
1792	Sangamon Co.	15.38	10.14	4.00	12849	14578
1812	Schuyler Co.	12.99	12.76	4.31	12709	14899
1868	Shelby Co.	11.26	13.63	4.93	12373	14686
1412	Tazewell Co.	14.30	11.49	3.90	12690	14623
1413	Tazewell Co.	14.35	12.45	3.53	12504	14569
720	Logan Co.	14.80	13.81	3.56	12426	14733
1889	Logan Co.	11.83	12.25	3.83	12376	14392

TABLE 19

BLUE BAND COAL

Lab. No.	Locality	Total Moisture	Referred to Dry Coal			"Unit Coal" Basis
			Ash	Sul.	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
742	Christian Co.	11.82	13.50	4.71	12203	14448
1870	Christian Co.	15.15	9.97	3.70	12745	14405
1871	Christian Co.	14.88	10.67	4.04	12696	14484
996	Clinton Co.	10.97	10.47	4.80	12815	14614
997	Clinton Co.	13.05	13.98	5.29	12232	14596
1177	Clinton Co.	15.19	11.15	1.65	12569	14342
1178	Clinton Co.	14.81	16.56	2.99	11639	14262
1175	Clinton Co.	11.83	10.78	3.96	12659	14459
1176	Clinton Co.	12.86	13.59	4.52	12246	14512
1845	Edgar Co.	14.94	11.00	3.02	12890	14734
1846	Edgar Co.	14.82	11.42	3.34	12797	14715
461	Franklin Co.	14.40	8.08	1.19	13400	14722
419	Franklin Co.	11.19	10.11	.60	12985	14597
420	Franklin Co.	10.06	7.53	.91	13312	14519
1810	Franklin Co.	10.13	10.29	.78	12945	14590
1722	Franklin Co.	8.47	10.55	2.13	12778	14491
1723	Franklin Co.	9.09	8.78	1.21	13173	14595
1776	Franklin Co.	9.11	6.42	1.33	13620	14679
1777	Franklin Co.	8.48	7.32	1.33	13527	14734
1799	Jackson Co.	7.81	13.20	3.85	12650	14897
1800	Jackson Co.	9.14	10.22	.68	12970	14603
1651	Jefferson Co.	7.48	11.35	3.34	12824	14735
1652	Jefferson Co.	7.85	12.10	4.19	12611	14655
735	Macoupin Co.	12.80	10.86	5.38	12469	14301
736	Macoupin Co.	12.71	11.40	4.41	12360	14238
737	Macoupin Co.	12.17	12.87	5.48	12303	14477
738	Macoupin Co.	12.80	11.90	4.33	12440	14419
1841	Macoupin Co.	12.89	12.68	6.49	12214	14369
1862	Macoupin Co.	13.93	12.29	5.23	12371	14441
725	Madison Co.	11.68	11.22	4.85	12762	14692
1117	Madison Co.	10.33	10.59	4.12	12681	14457
1118	Madison Co.	14.16	13.65	2.81	12114	14303
1119	Madison Co.	11.20	11.72	5.17	12499	14485
1866	Marion Co.	10.31	14.96	5.61	12167	14720
1842	Montgomery Co.	13.61	8.50	4.37	13473	14990
1864	Montgomery Co.	12.84	10.58	4.30	12743	14534
1863	Montgomery Co.	14.76	9.98	4.60	12712	14398
1873	Montgomery Co.	13.21	11.51	4.90	12570	14522
421	Perry Co.	9.31	14.71	.98	12181	14517
1523	Perry Co.	11.03	12.63	1.01	12453	14456
1614	Perry Co.	10.37	13.92	3.93	12293	14607
1615	Perry Co.	9.87	13.86	3.28	12261	14534
1591	Perry Co.	11.11	15.89	4.34	11859	14471
1592	Perry Co.	10.49	12.17	3.84	12361	14359
1835	Perry Co.	10.55	12.12	4.50	12393	14412
1610	Randolph Co.	10.72	14.55	5.07	11978	14385

TABLE 19

BLUE BAND COAL—(*Concluded*)

Lab. No.	Locality	Total Moisture	Referred to Dry Coal			"Unit Coal" Basis
			Ash	Sul.	B. t. u.	B. t. u. − 5000 S / 1.00 − (1.08 Ash + 22/40 S.)
1616	Randolph Co.	9.93	13.41	5.36	12245	14505
1120	Saline Co.	5.98	13.79	3.73	12505	14830
722	Sangamon Co.	14.96	11.04	4.55	12640	14503
1763	Sangamon Co.	14.69	10.98	4.95	12503	14349
739	Sangamon Co.	13.14	12.23	5.03	12372	14425
723	St. Clair Co.	12.11	12.23	4.37	12604	14676
724	St. Clair Co.	12.23	9.69	3.33	12982	14612
991	St. Clair Co.	9.76	15.80	4.76	12202	14895
995	St. Clair Co.	10.05	12.47	4.19	12587	14694
993	St. Clair Co.	9.44	11.23	4.37	12723	14630
1001	St. Clair Co.	13.75	12.53	2.13	12486	14512
1002	St. Clair Co.	13.15	13.43	3.23	12290	14486
1003	St. Clair Co.	9.41	12.94	4.90	12701	14948
1129	St. Clair Co.	15.91	11.07	4.70	12706	14593
1130	St. Clair Co.	11.11	12.00	4.72	12587	14625
1174	St. Clair Co.	15.46	12.73	4.02	12428	14549
1600	St. Clair Co.	11.43	15.14	5.69	11908	14435
557	Vermilion Co.	12.56	9.15	1.41	13058	14537
558	Vermilion Co.	12.96	8.03	1.78	13304	14626
1540	Vermilion Co.	17.73	11.95	1.15	12561	14463
1843	Vermilion Co.	13.23	11.43	3.17	12842	14761
1844	Vermilion Co.	13.41	9.76	3.52	13083	14748
1643	Washington Co.	10.41	11.34	4.35	12468	14351
1121	White Co.	6.71	11.50	4.46	12744-	14708
459	Williamson Co.	9.99	8.48	1.03	13323	14701
460	Williamson Co.	9.50	10.13	1.12	13078	14724
1088	Williamson Co.	6.69	10.65	2.50	13016	14795
462	Williamson Co.	9.39	7.66	1.89	13475	14754
1611	Williamson Co.	10.15	9.73	1.06	13229	14763
1612	Williamson Co.	6.12	13.76	4.42	12461	14799
1567	Williamson Co.	6.80	11.84	2.96	12788	14770
1613	Williamson Co.	9.69	10.23	1.16	13077	14742
1801	Williamson Co.	9.75	8.13	1.71	13438	14791
1805	Williamson Co.	7.58	12.10	3.85	12698	14745
1806	Williamson Co.	9.79	9.85	2.19	13048	14676
1804	Williamson Co.	6.77	13.29	5.08	12517	14800
1917	Williamson Co.	8.86	9.65	1.15	13103	14685
1918	Williamson Co.	9.34	9.50	1.74	13172	14739

APPENDIX A

TABLE 20

UNIT COAL VALUES

Compiled from Bulletin 9, Fourth Series, 1908, Ohio State Geological Survey

No.	County	Analyses of Coal as Received				"Unit Coal" Basis
		Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + \frac{22}{40}\text{ S.})}$
	Clarion or No. 4 Coal					
65	Lawrence	6.34	17.41	5.29	10741	14562
67	Lawrence	5.86	15.28	5.36	11133	14547
68	Lawrence	6.11	9.94	3.61	11957	14508
66	Lawrence	6.00	11.86	5.10	11734	14645
64	Scioto	6.80	9.34	3.45	11763	14272
63	Jackson	4.90	13.70	6.14	11495	14545
62	Jackson	5.31	13.54	6.08	11381	14436
55	Jackson	5.61	8.09	3.70	12279	14465
56	Jackson	4.98	9.80	4.08	12154	14538
57	Jackson	4.71	8.61	3.73	12361	14505
60	Jackson	5.33	8.40	3.72	12206	14387
59	Vinton	4.72	11.21	4.16	12049	14640
61	Vinton	4.52	8.85	4.23	12337	14505
54	Vinton	5.02	8.15	2.81	12469	14639
58	Vinton	4.61	11.10	5.28	12053	14645
70	Vinton	5.02	8.97	3.32	12528	14780
69	Vinton	4.95	9.32	3.53	12445	14775
	Average	5.34	10.80	4.33	11947	14551
	Lower Kittaning or No. 5 Coal					
74	Lawrence	7.57	8.79	3.20	12199	14830
75	Lawrence	8.07	9.71	2.13	11927	14727
76	Jackson	8.39	7.42	2.65	12190	14679
71	Perry	6.85	10.16	4.72	11864	14612
72	Perry	6.74	7.12	2.58	12393	14574
73	Muskingum	5.05	7.77	4.80	12569	14691
77*b*	Jefferson	2.46	7.40	3.82	13664	15406
77	Tuscarawas	5.30	7.71	3.25	12902	15061
77*a*	Mahoning	5.23	4.72	2.17	13504	15141
	Av	6.18	7.87	3.26	12578	14863
	Middle Kittaning or No. 6 Coal					
136	Lawrence	5.99	4.82	3.61	13165	14957
82*a*	Lawrence	6.64	10.92	3.32	11927	14749
82*b*	Gallia	8.08	8.52	3.64	12091	14753
89*a*	Athens	6.36	8.49	0.51	12454	14764
83	Athens	6.17	7.82	0.90	12362	14511
84	Athens	6.70	6.75	2.28	12458	14563

TABLE 20

UNIT COAL VALUES—(*Continued*)

No.	County	Analyses of Coal as Received				"Unit Coal" Basis
		Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
85	Athens	6.80	8.05	2.14	12229	14547
82	Vinton	4.90	10.15	4.25	12321	14802
81	Hocking	6.52	8.03	3.52	12330	14666
89	Athens	7.14	6.72	1.65	12353	14488
90	Athens	7.28	6.73	0.86	12409	14552
86	Hocking	7.55	5.85	0.77	12510	14552
87	Hocking	7.45	4.81	0.66	12703	14563
88	Hocking	7.40	5.00	1.06	12649	14542
80	Hocking	6.55	6.97	2.57	12422	14548
79	Perry	7.76	7.47	1.45	12190	14534
91	Perry	5.79	5.91	1.00	12569	14510
78	Perry	7.00	6.95	2.33	12384	14569
92	Perry	5.25	9.86	3.43	12191	14620
93	Perry	5.90	10.10	4.96	12035	14649
95	Perry	6.72	6.64	2.43	12425	14513
94	Perry	7.21	5.26	2.34	12614	14562
97	Perry	5.70	8.45	3.38	12332	14600
98	Perry	6.40	7.58	2.72	12361	14569
101	Muskingum	5.08	9.77	5.54	12244	14716
100	Muskingum	4.67	9.83	4.10	12371	14756
96	Muskingum	5.02	9.56	5.97	12164	14581
99	Muskingum	5.44	9.28	3.77	12280	14663
104	Muskingum	5.55	5.23	3.63	12944	14703
102	Muskingum	4.75	9.28	5.35	12337	14668
103	Muskingum	4.62	6.58	4.49	12827	14689
111	Coshocton	4.37	5.36	3.61	13045	14643
112	Coshocton	10.93	6.64	2.03	11039	13871*
108	Coshocton	4.33	5.59	4.00	13084	14736
109	Coshocton	5.12	7.02	3.87	12719	14708
105	Coshocton	5.32	6.30	4.22	12755	14661
110	Coshocton	5.60	13.28	4.87	11200	14159
113	Coshocton	4.44	4.45	3.54	13232	14702
114	Coshocton	4.58	8.75	5.36	12380	14589
118	Coshocton	5.32	8.60	4.36	12290	14546
120	Coshocton	4.50	5.97	3.63	12911	14623
107	Coshocton	5.40	5.08	3.18	12949	14641
133	Tuscarawas	3.45	7.67	5.22	12843	14733
131	Tuscarawas	3.41	9.38	4.88	12548	14686
115	Tuscarawas	4.72	5.47	4.05	12958	14637
130	Tuscarawas	3.78	8.42	3.83	12782	14808
129	Tuscarawas	3.81	6.01	3.24	13151	14774
124	Tuscarawas	4.10	5.21	3.25	13196	14730
134	Tuscarawas	3.18	6.93	4.12	13149	14865
116	Tuscarawas	5.19	5.87	3.55	12820	14613
128	Tuscarawas	4.30	7.63	3.97	12602	14546

* Low B. t. u. due to weathering.

TABLE 20

UNIT COAL VALUES—(*Continued*)

No.	County	Analyses of Coal as Received				"Unit Coal" Basis
		Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
117	Coshocton	4.70	11.29	5.60	11869	14481
106	Coshocton	5.30	6.15	3.72	12751	14609
121	Tuscarawas	3.52	6.01	3.17	13135	14705
122	Tuscarawas	4.94	9.50	4.19	12341	14706
123	Tuscarawas	3.51	7.69	4.56	12875	14761
132	Carroll	3.76	6.79	3.06	13028	14760
138	Tuscarawas	7.15	4.56	2.62	12949	14820
127	Tuscarawas	4.66	6.22	3.28	12775	14525
119	Holmes	7.31	4.21	1.00	12514	14230
125	Tuscarawas	4.69	9.06	4.70	12386	14649
126	Tuscarawas	4.92	7.04	2.91	12748	14676
135	Stark	6.66	8.22	2.66	12559	14971
137	Columbiana	3.60	4.60	1.76	14020	15401
139	Stark	5.65	10.08	4.13	12362	14973
	Av	5.56	7.36	3.30	12564	14644
	Upper Freeport, Waterloo or No. 7 Coal					
147	Lawrence	7.20	10.67	2.33	11801	14824
144	Lawrence	7.85	12.18	2.66	11349	14465
145	Lawrence	8.37	8.23	1.29	11873	14396
146	Lawrence	8.45	11.28	0.93	11529	14547
142	Gallia	7.62	12.39	1.81	11468	14586
140	Lawrence	7.13	8.91	1.31	12089	14570
141	Lawrence	8.77	8.71	0.76	11855	14517
143	Lawrence	8.38	10.09	1.84	11695	14556
	Av	7.97	10.31	1.62	11707	14531
	Upper Freeport or No. 7 Coal					
148	Muskingum	4.89	7.78	4.36	12499	14566
149	Muskingum	4.72	7.56	5.00	12683	14736
150	Muskingum	5.11	12.60	3.84	11804	14667
151	Coshocton	6.40	3.19	2.01	13185	14694
	Av	5.28	7.78	3.80	12542	14665

TABLE 20

UNIT COAL VALUES—(*Continued*)

No.	County	Analyses of Coal as Received				"Unit Coal" Basis
		Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
	Pittsburg or No. 8 Coal					
25	Gallia	5.80	10.06	4.34	11792	14301
27	Gallia	6.98	9.03	5.21	11849	14413
28	Gallia	7.83	9.76	3.89	11779	14575
26	Gallia	6.73	13.03	4.37	11441	14614
23	Athens	5.78	8.00	4.19	12299	14618
24	Athens	6.60	10.20	3.41	11892	14560
24	Athens	4.51	11.49	4.88	11945	14553
22	Morgan	6.87	8.19	4.22	12100	14504
9	Belmont	2.79	9.42	5.09	12987	14134
11	Belmont	4.08	10.61	4.95	12476	14961
8	Belmont	2.91	8.00	4.31	13212	15099
3	Belmont	3.51	6.86	3.76	13185	14937
4	Belmont	3.80	8.95	4.27	12785	14933
7	Belmont	3.21	7.26	4.28	13135	14920
10	Belmont	4.47	11.01	4.67	12375	14976
6	Belmont	3.75	10.84	4.76	12357	14794
5	Belmont	4.46	10.76	4.45	12425	14977
1	Belmont	3.39	7.86	2.97	12991	14850
2	Belmont	3.79	9.00	4.16	12861	15027
6*a*	Belmont	4.25	10.35	3.95	12425	14840
2*a*	Belmont	4.23	9.21	4.17	12605	14842
12	Jefferson	3.10	9.52	3.83	12875	15008
15	Jefferson	3.13	8.22	4.02	13019	14943
15*a*	Jefferson	4.57	9.00	1.55	12789	14980
18	Harrison	6.54	6.74	2.19	12710	14829
21	Harrison	5.98	5.97	1.35	12964	14853
20	Harrison	3.83	10.88	4.38	12355	14798
16	Jefferson	4.89	10.46	4.09	12515	15095
13	Jefferson	4.96	6.45	1.75	13099	14938
19	Jefferson	4.18	8.22	2.83	12888	14928
14	Jefferson	4.30	7.88	3.01	12859	14858
17	Jefferson	5.05	7.95	2.61	12865	14995
	Av.	4.70	9.10	3.81	12559	14835
	Pomeroy or No. 8*a* Coal					
34	Gallia	8.21	11.46	2.18	11497	14561
33	Meigs	4.85	12.52	2.94	11923	14718
29	Meigs	7.33	8.69	2.05	12105	14608
30	Meigs	7.22	9.29	1.32	12002	14552
31	Meigs	5.51	10.58	4.17	11990	14588
32	Meigs	7.63	10.93	1.83	11722	14618
	Av.	6.79	10.58	2.42	11873	14608

TABLE 20

UNIT COAL VALUES—(*Concluded*)

No.	County	Analyses of Coal as Received				"Unit Coal" Basis
		Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
	Meigs Creek or No. 9 Coal					
53	Washington	2.95	12.89	5.55	12245	14946
52	Washington	3.40	9.58	5.03	12749	14970
44	Noble	3.06	12.33	6.00	12357	15011
45	Noble	2.90	10.16	4.27	12692	14895
43	Noble	2.55	11.41	5.79	12514	14918
42	Noble	3.12	12.85	5.60	12130	14827
50	Morgan	5.13	11.74	4.89	11925	15270
48	Morgan	5.05	10.37	4.30	12114	14621
49	Morgan	4.07	10.66	5.07	12202	14637
47	Noble	3.54	13.23	6.21	11956	14787
46	Noble	4.85	9.82	5.59	12301	14757
37	Belmont	4.47	13.07	3.27	12002	14870
40	Belmont	3.40	14.94	4.39	11840	14890
41	Belmont	3.52	11.84	3.67	12391	14947
39	Belmont	4.17	9.60	3.11	12602	14863
38	Belmont	4.31	11.68	1.94	12307	14888
36*a*	Belmont	7.52	11.24	2.11	11860	14846
36	Belmont	4.98	12.82	2.41	11974	14846
35	Harrison	5.35	10.29	2.20	12393	14919
	Av.	4.11	11.60	4.28	12240	14845

APPENDIX B

TABLE 21

UNIT COAL VALUES

Compiled from Bulletins 261, 290, 332, United States Geological Survey

State No.	Table No.	County	Analyses of Coal as Received: Moisture	Ash	Sulphur	B. t. u.	"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
		Alabama					
1	1078M*	Walker........	1.35	13.63	.71	12991	15509
1	1201C *	Walker........	2.34	12.54	.72	12856	15313
2	1075M	Walker........	2.25	9.04	1.09	13133	14967
2	1076M	Walker........	2.42	11.13	1.10	12695	14879
2	3011M	Walker........	4.71	10.17	1.33	12596	14992
2	1225C	Walker........	3.36	12.43	1.01	12350	14879
2	3211C	Walker........	3.95	14.59	1.12	11785	14722
3	3018M	Bibb..........	3.03	10.72	.49	13034	15285
3	3255C	Bibb..........	2.72	14.36	.55	12461	15263
4	3034M	Bibb..........	3.67	3.14	1.22	14396	15536
4	3103C	Bibb..........	6.43	12.92	1.08	12395	15616
5	4091M	Blount........	2.93	2.73	.65	14693	15636
5	4252C	Blount........	5.59	16.08	1.40	11906	15518
6	4293M	Jefferson......	2.81	3.51	.59	14643	15701
5	4338C	Jefferson.......	3.23	6.71	.61	14074	15747
		Arkansas					
1	1045M	Sebastian......	1.02	7.49	1.10	14434	15927
1	2585M	Sebastian......	3.53	7.77	1.29	14017	15971
1	1114C	Sebastian......	3.24	12.61	1.24	13129	15846
1	2689C	Sebastian......	7.49	17.97	1.06	11369	15604
2	1049M	Sebastian......	.95	6.97	2.12	14387	15806
2	1160C	Sebastian......	2.23	9.20	1.87	13750	15733
3	1115M	Sebastian......	1.60	7.91	1.42	14162	15818
3	1296C	Sebastian......	2.19	11.63	1.28	13464	15849
5	1130M	Franklin.......	1.38	6.95	1.52	14330	15790
5	1331C	Franklin.......	2.36	12.08	1.99	13259	15761
7	2593M	Sebastian......	3.97	5.91	1.53	14236	15945
7	2688C	Sebastian......	5.47	11.69	2.02	12690	15582
7	2722C	Sebastian......	6.89	15.00	2.24	12060	15787
8	2587M	Johnson.......	3.12	8.46	1.84	13793	15797
8	2744C	Johnson.......	5.19	14.01	2.05	12460	15731
9	2599M	Sebastian......	1.99	7.06	1.05	14087	15628
9	2690C	Sebastian......	5.26	24.81	1.00	10451	15434
10	2647M	Ouachita......	39.50	12.58	.53	5877	12551
10	2726C	Ouachita......	39.43	9.71	.49	6356	12717
13	3798M	Franklin.......	2.91	17.51	3.12	12312	15898
13	4626C	Franklin.......	1.76	14.96	2.29	12926	15853

* Samples marked M are mine samples: those marked C are car samples of various sizes of coal.

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
		California					
1	1607M	Alameda......	18.02	16.37	3.07	8105	12699
1	1680C	Alameda......	18.51	15.49	3.05	8507	13243
		Colorado					
1	1383M	Boulder.......	20.02	3.61	.52	10237	13477
1	1523C	Boulder.......	18.68	5.99	.55	10143	13570
		Florida					
1	3270C	Orange........	21.00	5.17	.45	8127	11076
		Georgia					
1	4156M	Chattanooga...	2.85	7.84	.67	14198	16039
1	4320C	Chattanooga...	3.80	14.49	1.27	12791	15939
		Illinois					
24	2854M	Clinton........	13.43	9.18	3.35	10937	14395
24	2972C	Clinton........	11.44	10.71	4.94	10958	14422
25	2856M	Clinton........	11.64	8.66	3.41	11290	14416
35	2991C	Clinton........	11.35	13.40	4.76	10733	14666
23	4385M	Clinton........	15.06	9.65	1.05	10726	14435
10	1648C	Franklin.......	9.50	11.44	1.45	11506	14783
13	1694M	Franklin.......	9.46	8.12	1.63	11990	14745
13	1786C	Franklin......	8.31	10.48	1.55	11727	14651
19	1871M	Franklin......	9.90	7.74	.48	12001	14699
19	1926C	Franklin......	14.91	8.93	.52	10958	14545
19	2020C	Franklin......	10.72	9.36	.91	11686	14800
18	1741M	La Salle.......	13.87	10.31	3.44	10985	14790
18	1779C	La Salle.......	12.39	8.92	3.92	11399	14784
26	3003	Logan.........	15.68	12.09	3.51	10215	14482
9	1625M	Macoupin......	13.29	8.90	4.12	11162	14641
9	1635C	Macoupin......	13.54	10.74	4.03	10807	14599
9	1639C	Macoupin......	13.72	10.32	3.96	10870	14627
9	4247C	Macoupin......	15.25	15.35	3.81	9790	14528
20	2731C	Macoupin......	14.68	13.68	3.88	10053	14409
4	1341M	Madison.......	15.09	7.42	.83	11151	14533
4	1417C	Madison.......	12.91	11.64	1.32	10804	14552

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
5	1556C	Madison	17.02	16.79	3.29	9319	14523
7	1609M	Madison	11.87	11.58	4.75	10768	14425
7	1611C	Madison	11.46	17.31	4.40	10026	14542
7	1780C	Madison	10.83	13.18	4.53	10816	14618
21	2770M	Madison	15.23	9.03	1.59	10901	14595
21	2852C	Madison	15.54	10.93	1.38	10507	14517
22	2772M	Madison	13.51	10.15	4.01	10881	14566
22	2905C	Madison	11.91	13.01	5.34	10615	14554
22	2896C	Madison	13.03	14.53	4.35	10192	14480
23	2774M	Madison	13.07	10.06	3.59	10949	14535
23	2819C	Madison	13.47	11.53	4.41	10510	14360
23	2803C	Madison	15.68	15.59	3.98	9655	14483
29	3911M	Madison	14.25	9.44	3.72	10892	14566
29	3913M	Madison	12.69	8.76	3.62	11236	14571
29	3958C	Madison	12.47	12.56	4.37	10667	14602
29	3963C	Madison	13.10	16.00	4.17	9983	14519
29	3980C	Madison	12.25	12.33	4.42	10719	14578
15	1725M	Marion	10.25	12.53	3.70	11077	14683
15	1761C	Marion	9.95	13.23	3.87	10960	14622
6	1449M	Montgomery	14.89	7.87	3.61	11016	14518
6	1661M	Montgomery	12.90	11.08	3.78	10856	14602
6	1557C	Montgomery	14.43	13.28	4.01	10064	14290
6	1702C	Montgomery	11.93	14.18	4.29	10303	14332
8	1627C	Montgomery	13.20	12.53	4.47	10514	14673
1	1095M	St. Clair	11.17	10.32	4.22	11223	14612
1	1261C	St. Clair	9.75	13.20	4.10	11025	14675
2	1152C	St. Clair	12.03	22.44	4.00	9149	14542
30	3912M	St. Clair	9.88	10.81	3.83	11439	14733
30	4364C	St. Clair	11.69	13.19	4.38	10699	14625
31	4251M	St. Clair	14.38	8.75	3.13	10858	14375
31	4376C	St. Clair	13.10	13.25	3.66	10363	14423
14	1704M	Sangamon	13.89	11.26	3.83	10636	14540
14	1740C	Sangamon	12.77	11.78	4.16	10757	14607
27	2897M	Sangamon	14.29	8.18	4.41	11007	14488
27	3052C	Sangamon	16.00	13.77	4.05	9940	14554
34	4414M	Saline	7.51	7.48	1.58	12686	15091
34	4636C	Saline	9.33	11.89	2.76	11572	14984
34	4622C	Saline	7.81	8.38	2.36	12418	15029
3	1170M	Williamson	7.50	7.15	.99	12386	14646
3	1318C	Williamson	8.50	11.28	1.72	11776	14916
11	1634M	Williamson	8.30	9.26	2.82	11999	14794
11	1654C	Williamson	7.76	10.61	1.97	11957	14835
11	1660C	Williamson	8.86	11.66	2.46	11702	14956
11	1718C	Williamson	8.61	7.66	1.65	12236	14797
12	1683M	Williamson	8.29	10.83	2.81	11837	14867
12	1762C	Williamson	8.20	12.95	3.48	11362	14740

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
12	4201C	Williamson....	15.87	9.52	2.34	10784	14701
12	3907C	Williamson....	12.61	10.50	2.37	11066–	14647
12	4085C	Williamson....	15.31	10.47	2.32	10820	14846
16	1731M	Williamson....	9.37	7.37	1.25	12058	14632
16	1820C	Williamson....	8.43	9.60	1.14	11959	14772
28	3629M	Williamson....	8.72	7.62	1.00	12200	14727
28	3789C	Williamson....	7.78	9.98	1.32	11959	14770
		INDIANA					
20	3536M	Clay..........	15.38	5.88	1.95	11680	15004
20	3979C	Clay..........	16.91	17.37	1.89	9524	14900
15	3473M	Greene........	13.53	7.55	.95	11738	15028
15	3567C	Greene........	13.58	8.15	.91	11419	14749
16	3564C	Greene........	10.30	11.75	4.23	11218	14737
17	3516M	Knox..........	10.60	8.30	3.69	11752	14754
17	3981C	Knox..........	12.08	11.02	3.65	11011	14630
10	1853M	Parke.........	11.54	9.62	4.41	11655	15116
10	1979C	Parke.........	10.72	8.57	3.83	11767	14857
19	3534M	Parke.........	13.70	5.91	2.66	11930	15036
7	1824M	Pike..........	10.18	8.12	3.96	12181	15193
7	1881C	Pike..........	8.90	9.21	3.74	12008	14946
7	1882C	Pike..........	11.12	9.35	3.78	11549	14811
12	2701M	Pike..........	11.29	6.87	3.09	11921	14772
12	2759C	Pike..........	10.57	11.65	3.87	11266	14818
18	3525M	Pike..........	12.88	6.14	1.70	11801	14728
18	3801C	Pike..........	11.13	6.98	1.64	12031	14856
1	1410M	Sullivan.......	13.25	9.16	1.87	11360	14857
1	1507C	Sullivan.......	11.40	13.40	2.50	11061	15032
4	1775M	Sullivan.......	14.86	7.35	2.26	11324	14759
4	1844C	Sullivan.......	13.99	14.32	2.31	10318	14730
5	1773M	Sullivan.......	12.14	8.96	3.54	11516	14875
5	1859C	Sullivan.......	12.03	10.88	4.27	11192	14726
6	1772M	Sullivan.......	10.45	9.58	4.04	11745	14995
6	1875C	Sullivan.......	10.80	12.62	4.39	11185	14990
11	1883M	Sullivan.......	14.23	5.72	.89	11722	14764
11	2087C	Sullivan.......	12.15	8.14	1.41	11761	14934
8	1828M	Vigo..........	10.68	12.24	4.38	11261	14984
8	2037C	Vigo..........	9.55	10.61	3.72	11759	15042
9	1848M	Vigo..........	13.73	8.65	3.00	11360	14891
9	1960C	Vigo..........	13.53	10.76	3.15	10948	14759
9	1973C	Vigo..........	12.82	10.30	3.27	11119	14752
13	3467M	Vigo..........	13.43	7.34	2.16	11448	14642
13	3748C	Vigo..........	12.97	12.09	3.18	10899	14871
14	3491M	Vigo..........	13.62	7.11	3.28	11543	14797
14	3775C	Vigo..........	7.88	14.20	5.14	11146	14725

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + \frac{22}{40}\ \text{S.})}$
2	1425M	Warrick.......	9.28	9.34	4.44	11799	14806
2	1495C	Warrick.......	9.62	13.02	4.43	11122	14754
3	1759M	Warrick.......	11.28	7.63	3.58	11792	14792
3	1941C	Warrick.......	13.18	15.63	4.79	10030	14547
			IOWA				
1	1270M	Davis..........	11.35	10.51	4.72	11345	14871
1	1347C	Davis..........	8.24	16.00	5.03	11027	15026
2	1289M	Marion.........	15.65	11.64	5.10	10289	14548
2	1570C	Marion.........	14.21	15.22	4.66	10019	14652
3	1312M	Polk...........	14.42	10.99	5.89	10640	14680
3	1434C	Polk...........	13.88	14.01	6.15	10244	14698
4	1323M	Appanoose.....	17.13	7.07	4.00	10931	14694
4	1437C	Appanoose.....	14.08	10.96	4.26	10723	14650
5	1332M	Lucas..........	18.69	7.73	2.39	10505	14496
5	1433C	Lucas..........	15.39	12.63	3.19	10242	14567
			INDIAN TERRITORY				
		(Town)					
1	1059M	Henryetta.....	8.87	8.63	1.62	12096	14848
1	1138C	Henryetta.....	7.04	10.01	1.92	12202	14929
2	1071M	Hartshorne....	1.46	6.40	1.38	14040	15375
2	1184C	Hartshorne....	4.45	11.00	1.52	12607	15129
3	1080M	Edwards......	2.93	10.30	3.73	12591	14786
3	1274C	Edwards......	4.61	11.14	3.63	12319	14918
4	1151M	Lehigh........	6.50	9.31	3.67	11842	14318
4	1470C	Lehigh........	6.24	13.21	3.96	11228	14267
5	1481C	Lehigh........	8.29	25.05	3.95	9110	14264
9	4020C	Panama.......	5.11	8.03	1.18	13662	15897
			KANSAS				
		(County)					
1	1018M	Crawford......	2.91	9.55	3.79	12947	15063
1	1097C	Crawford......	4.99	12.97	4.28	12242	15293
2	1017M	Crawford......	2.44	10.60	5.63	13043	15373
2	1122C	Crawford......	4.18	17.91	6.27	11642	15511
3	1037M	Cherokee......	2.54	9.87	4.47	13340	15535
3	1086C	Cherokee......	2.50	12.45–	5.68	12900	15589
4	1473C	Atchison......	6.95	12.19	8.04	11905	15244
5	1411M	Cherokee......	5.11	8.90	4.34	12926	15332
5	1567C	Cherokee......	4.10	10.54	3.77	12895	15412
6	2790M	Linn...........	11.13	12.60	2.41	11219	15011
6	2843C	Linn...........	9.04	15.72	3.72	11142	15231

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received: Moisture	Ash	Sulphur	B. t. u.	"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ S}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ S.)}$
		KENTUCKY					
1	1321M	Bell..........	2.91	3.53	.89	14322	15280
1	2350M	Bell..........	3.42	3.18	1.53	14375	15491
1	1474C	Bell..........	3.10	4.39	1.22	14148	15397
1	2445C	Bell..........	5.21	8.22	1.12	13214	15427
2	1365M	Hopkins.......	8.49	7.10	3.53	12344	14858
2	1461C	Hopkins.......	7.91	9.13	3.62	12200	14979
3	1367M	Hopkins.......	7.98	9.30	4.03	11965	14748
3	1506C	Hopkins.......	7.92	10.06	3.52	12022	14944
4	1382M	Webster.......	4.61	7.40	3.33	12861	14836
4	1539C	Webster.......	5.27	14.18	4.54	11950	15240
5	2270M	Harlan........	4.32	2.28	.48	14121	15165
5	2528C	Harlan........	4.36	3.70	.67	13923	15217
6	2405M	Johnson.......	6.95	2.03	.48	13687	15054
6	2592C	Johnson.......	5.12	2.76	.57	13743	14975
7	2453M	Muhlenberg....	8.76	9.42	4.07	11965	14919
7	2595C	Muhlenberg....	8.47	9.48	3.60	11986	14886
8	3678M	Union.........	7.46	4.60	.97	13489	15443
8	3860C	Union.........	5.46	7.92	1.18	13239	15444
9	3722M	Ohio..........	10.03	7.67	2.56	12076	14758
9	3723M	Ohio..........	9.89	8.69	2.45	11927	14872
9	3865C	Ohio..........	8.70	8.96	3.14	12078	14922
		MARYLAND					
1	2018M	Garrett........	2.47	9.55	1.23	13853	15936
1	2274C	Garrett........	2.33	13.13	1.49	13255	15942
		MISSOURI					
1	1043M	Bates.........	4.92	14.52	5.34	11992	15334
1	1126C	Bates.........	8.33	19.36	5.25	10586	15209
2	1226M	Macon........	14.74	7.78	3.79	11185	14705
2	1348C	Macon........	11.50	16.86	5.16	10179	14709
3	1549C	Putnam.......	15.71	20.78	3.69	8840	14471
4	1446M	Morgan.......	13.34	6.91	5.06	11605	14855
4	1516C	Morgan.......	12.67	4.83	5.12	12487	15426
5	2795M	Randolph.....	13.38	10.02	4.48	11084	14808
5	2865C	Randolph.....	12.92	13.62	5.03	10548	14793
6	2817M	Randolph......	14.01	10.29	5.23	11030	14955
6	2904C	Randolph......	13.80	11.74	5.60	10796	14929
7	2823M	Adair.........	17.19	9.28	2.76	10598	14677
7	2936C	Adair.........	16.36	19.51	3.53	9007	14566
7	2942C	Adair.........	17.30	23.38	2.94	8240	14496
7	2937C	Adair.........	16.39	20.18	3.12	8946	14626
10	4197M	Macon........	15.41	11.61	3.78	10582	14853
10	4257C	Macon........	15.23	20.50	3.69	9099	14712

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
		Montana					
1	1298C	Carbon	11.05	10.97	1.73	10539	13727
2	4234C	Carbon	8.51	15.39	.60	10478	14017
3	4271C	Carbon	8.56	13.39	.54	10685	13899
		New Mexico					
1	(1025)M (1026)M	McKinley	10.96	4.01	.52	11885	14048
1	1278C	McKinley	12.29	6.99	.63	11252	14058
2	1028M	McKinley	9.68	8.08	1.55	11623	14301
2	1307C	McKinley	10.79	18.66	1.26	9907	14398
3	3221M	Colfax	2.50	9.13	.72	13127	15006
3	3295C	Colfax	3.45	16.67	.73	11893	15173
3	3307C	Colfax	4.36	15.92	.83	11912	15220
3	3308C	Colfax	2.75	15.52	.64	12166	15141
4	3228M	Colfax	2.19	11.11	.57	13063	15246
4	3331C	Colfax	2.78	14.57	.61	12294	15113
4	3315C	Colfax	3.38	13.54	.61	12445	15202
5	3226M	Colfax	2.25	12.37	.75	13030	15472
5	3294C	Colfax	2.72	14.57	.69	12539	15408
		North Dakota					
1	1971M	Stark	42.06	7.66	1.13	6158	12441
1	1279C	Stark	35.38	9.35	1.55	6923	12756
1	2289C	Stark	32.64	11.42	3.54	6970	12798
2	1730M	Williams	41.13	5.36	.72	6485	12242
2	1416C	Williams	36.78	5.09	.48	7204	12496
2	2365C	Williams	36.13	5.04	.59	7326	12558
3	1935M	McLean	40.53	5.05	.76	6644	12325
3	2243C	McLean	35.96	7.75	1.15	7069	12740
		Ohio					
6	2095M	Belmont	3.99	8.07	3.49	13102	15144
6	2392C	Belmont	5.31	8.52	3.33	12843	15153
11	3986M	Belmont	4.13	7.96	4.12	13088	15155
11	4157C	Belmont	3.44	12.94	4.32	12287	15049
12	4151C	Belmont	4.14	9.38	3.96	12874	15172
12	4178C	Belmont	2.97	9.97	3.65	12933	15133
7	2090M	Guernsey	6.28	7.30	3.55	12701	14930
7	2656C	Guernsey	6.65	10.55	3.13	12179	14984

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received: Moisture	Ash	Sulphur	B. t. u.	"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + \frac{22}{40}\text{ S.})}$
1	1896M	Jackson.	8.45	6.73	3.10	12249	14647
1	2071C	Jackson.	7.71	11.95	4.61	11515	14685
2	1898M	Jackson.	9.38	7.62	4.08	11898	14590
2	2109C	Jackson.	9.01	11.34	4.02	11495	14758
4	1910M	Jefferson.	4.06	7.75	3.67	13147	15152
4	2083C	Jefferson.	3.53	9.12	3.47	13072	15226
5	1944M	Jefferson.	4.69	6.01	1.54	13325	15060
5	2062C	Jefferson.	4.34	7.30	1.72	13178	15078
3	1900M	Perry.	10.78	6.13	1.11	11993	14563
3	2144C	Perry.	9.90	11.58	1.81	11277	14605
8	2119M	Perry.	8.92	5.85	3.00	12328	14653
8	2559C	Perry.	7.55	8.37	2.84	12128	14644
10	3969M	Tuscarawas. . . .	4.46	8.54	3.73	12845	15022
10	4059C	Tuscarawas. . . .	4.49	7.53	2.93	12958	14938
9	2208M	Vinton.	6.79	7.66	3.34	12514	14858
9	2310C	Vinton.	5.59	8.29	3.15	12773	15068
9	2311C	Vinton.	8.10	11.93	3.35	11563	14766
		PENNSYLVANIA					
10	2080M	Allegheny.	3.67	5.46	1.37	13874	15395
10	2229C	Allegheny.	2.61	6.17	1.26	13997	15475
13	3437M	Allegheny.	2.53	8.98	2.21	13356	15303
13	3879C	Allegheny.	2.65	13.16	2.16	12816	15507
8	2014M	Cambria.	3.49	5.71	.95	14515	16108
8	2152C	Cambria.	3.51	6.63	.94	14279	16025
16	4029M	Cambria.	2.74	7.23	1.51	14144	15876
16	4169C	Cambria.	4.25	7.87	1.59	13513	15553
18	4348M	Cambria.	2.66	8.56	2.97	13995	16014
18	4509C	Cambria.	4.46	8.47	1.49	13682	15903
21	4412M	Fayette.	2.82	7.37	1.22	13991	15731
21	4609C	Fayette.	5.13	8.71	.86	13365	15675
15	4027M	Indiana.	2.84	8.27	3.11	14079	16094
15	4082C	Indiana.	3.13	9.81	3.77	13795	16159
15	4104C	Indiana.	2.57	10.33	3.97	13712	16072
17	4337	Indiana.	2.22	8.42	1.54	13801	15624
17	4421	Indiana.	4.35	11.90	1.51	12964	15725
9	2016M	Somerset.	2.63	10.21	2.05	13705	15963
9	2199C	Somerset.	3.09	11.33	2.04	13424	15945
5	1966M	Washington. . . .	3.01	4.83	.73	14197	15499
5	2068C	Washington. . . .	2.46	6.05	.88	14013	15430
11	3421M	Washington. . . .	2.50	5.34	1.14	14146	15465
11	3532C	Washington. . . .	1.95	7.29	1.18	13775	15320
12	3441M	Washington. . . .	2.60	5.63	1.19	14184	15689
12	4098C	Washington. . . .	1.96	9.25	2.19	13622	15560

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received: Moisture	Ash	Sulphur	B. t. u.	"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
4	1942M	Westmoreland..	2.73	9.13	1.33	13613	15629
4	2187C	Westmoreland..	3.15	10.41	1.26	13406	15714
6	1968M	Westmoreland..	4.08	9.50	1.64	13268	15557
6	2161C	Westmoreland..	3.24	12.52	1.94	12879	15555
7	1994M	Westmoreland..	3.30	11.18	1.79	13378	15887
7	2154C	Westmoreland..	4.09	12.47	2.08	13153	16050
19	4352M	Westmoreland..	2.01	6.32	1.39	14152	15579
19	4489C	Westmoreland..	3.39	8.36	1.05	13699	15685
20	4350M	Westmoreland..	2.48	9.24	3.03	13822	15936
20	4517C	Westmoreland..	4.00	10.54	2.85	13347	15899
22	4498C	Westmoreland..	3.98	10.16	1.00	13311	15693
		TENNESSEE					
1	2907M	Claiborne.	3.71	4.74	1.28	13804	15195
1	3016C	Claiborne......	4.81	11.15	1.58	12569	15180
2	2931M	Campbell......	3.61	3.41	.83	14130	15271
2	3129C	Campbell......	5.09	6.81	.98	13295	15222
3	2929M	Campbell......	4.25	4.13	.93	13666	15004
3	3040C	Campbell......	5.38	7.05	.99	13048	15033
4	2956M	Roane.........	3.25	6.61	.85	13514	15112
4	3058C	Roane.........	6.39	9.53	.98	12578	15135
5	2958M	Morgan.......	2.25	6.91	2.96	13851	15456
5	3050C	Morgan.......	5.59	9.76	3.23	12841	15445
6	2977M	Cumberland....	3.80	4.50	.78	14182	15557
6	3102C	Cumberland....	3.89	14.43	.78	12514	15574
7	2979M	Fentress.......	3.46	9.08	2.42	12983	15073
7	3133C	Fentress.......	3.03	12.85	3.26	12602	15300
8	3005M	White.........	3.01	10.76	3.42	13104	15490
8	3127C	White.........	2.63	13.42	4.38	12715	15529
8	3128C	White.........	3.12	14.12	4.74	12517	15540
9	2995M	Grundy.......	3.44	9.21	.73	13219	15292
9	3113C	Grundy.......	3.92	14.09	.94	12508	15510
9	3114C	Grundy.......	5.68	18.55	.74	11480	15489
9	3115C	Grundy.......	4.68	9.26	.65	13163	15454
10	3009M	Marion........	3.31	13.11	1.30	12193	15825
11	3471C	Cumberland....	3.53	27.87	.90	10264	15514
		TEXAS					
1	1196M	Houston.......	33.50	10.75	.56	7142	13034
1	1456C	Houston.......	34.70	11.20	.79	7056	13298
2	1241M	Wood.........	28.86	7.92	.50	7996	12794
2	1597C	Wood.........	33.71	7.28	.53	7348	12594

TABLE 21

UNIT COAL VALUES—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + \frac{22}{40}\text{ S.})}$
3	2652M	Milan	36.01	7.38	.77	7132	12759
3	2734C	Milan	31.06	7.88	.99	7870	13059
4	2635M	Wood	36.80	6.25	.53	7101	12598
4	2717C	Wood	33.85	7.30	.51	7497	12885
		UTAH					
1	3199C	Carbon	6.05	4.87	.55	13151	14848
2	3200M	Summitt	14.07	6.26	1.28	10471	13262
		VIRGINIA					
1	2268M	Lee	5.69	8.11	2.31	13117	15428
1	2420C	Lee	4.06	4.73	1.20	13826	15267
2	2476C	Lee	3.35	5.58	.92	13932	15410
3	2382C	Wise	3.05	4.48	.67	14470	15736
4	2323M	Lee	3.89	3.06	.34	14144	15253
4	2358C	Lee	4.35	4.33	.79	13939	15353
5	4093M	Montgomery	2.98	21.94	.68	11669	15949
5	4287C	Montgomery	4.80	18.03	.63	11961	15825
5	4294C	Montgomery	7.52	16.23	.65	11893	15900
6	4305M	Tazewell	2.60	4.48	1.35	14636	15867
6	4573C	Tazewell	5.62	9.79	1.21	13264	15880
		WASHINGTON					
1	2456M	King	17.97	7.78	.43	10006	13604
1	2687C	King	16.04	11.53	.61	9938	13920
1	2686C	King	14.30	11.37	.72	10208	13930
2	2458M	Kittitas	3.39	10.39	.33	12847	15059
2	3098C	Kittitas	3.16	12.26	.38	12586	15070
		WEST VIRGINIA					
6	1176M	Fayette	2.10	3.55	.75	14900	15870
6	1390C	Fayette	1.53	5.05	.65	14807	15944
7	1198M	Fayette	2.12	3.55	.90	14915	15895
7	1595C	Fayette	3.94	4.93	1.16	14382	15898
8	1257M	Fayette	1.90	4.87	.64	14452	15591
8	1515C	Fayette	4.16	7.17	.90	13786	15686
9	1208M	Fayette	1.98	3.76	.85	14738	15825
9	1561C	Fayette	4.08	6.58	.77	13925	15712

TABLE 21

Unit Coal Values—(*Continued*)

State No.	Table No.	County	Analyses of Coal as Received				"Unit Coal" Basis
			Moisture	Ash	Sulphur	B. t. u.	$\frac{\text{B. t. u.} - 5000\ \text{S}}{1.00 - (1.08\ \text{Ash} + {}^{22}/_{40}\ \text{S.})}$
13	1867M	Fayette	5.48	2.29	.79	14454	15734
13	2028C	Fayette	3.74	3.91	.89	14436	15721
14	1870M	Fayette	2.96	7.44	1.04	13972	15741
14	2004C	Fayette	5.09	3.27	1.03	14110	15480
19	2359M	Fayette	3.26	2.46	.78	14773	15733
19	2549C	Fayette	2.96	5.01	.89	14425	15780
2	1103M	Harrison	1.98	9.08	4.20	13466	15432
2	1308C	Harrison	1.95	7.86	3.48	13790	15536
15	2039M	Harrison	2.80	5.55	2.40	14105	15558
15	2195C	Harrison	2.01	8.55	2.54	13811	15664
20	2375M	Kanawha	2.66	4.44	1.14	14368	15571
20	2556C	Kanawha	2.82	8.03	1.38	13766	15609
21	2377M	Kanawha	3.57	3.62	1.14	14173	15362
21	2572C	Kanawha	3.57	4.85	1.32	13948	15346
22	3456M	Kanawha	2.75	5.49	.63	13813	15149
22	3457M	Kanawha	3.49	6.44	.63	13813	15449
22	3905C	Kanawha	3.42	7.82	.83	13486	15335
23	3458M	Kanawha	3.13	3.54	.59	13963	15027
23	3965C	Kanawha	2.05	8.10	1.35	13707	15420
23	3625C	Kanawha	3.25	7.58	1.22	13523	15317
25	4291M	Kanawha	3.91	7.68	.64	13471	15199
25	4360C	Kanawha	4.21	7.22	.64	13379	15229
11	1234M	McDowell	2.21	5.25	.44	14792	16075
11	1472C	McDowell	4.07	11.12	.51	13509	16122
12	1238M	McDowell	1.92	4.39	.52	14926	16013
12	1242M	McDowell	3.48	3.90	.73	14731	15989
12	1364C	McDowell	1.72	6.87	.68	14571	16065
1	1088M	Marion	1.40	6.67	1.59	14063	15447
1	1213C	Marion	1.75	6.34	.90	14107	15450
16	2041M	Marion	2.89	5.71	.69	14540	16020
16	2264C	Marion	5.57	8.37	1.20	13093	15701
10	1240M	Mercer	2.93	3.62	.48	14924	16039
10	1471C	Mercer	1.75	4.58	.56	15023	16125
18	2348M	Mingo	2.81	6.50	.66	13957	15504
18	2527C	Mingo	2.86	5.83	.67	14106	15554
3	1108M	Monongalia	2.90	8.19	.75	13941	15829
3	1252C	Monongalia	2.29	10.23	1.06	13558	15689
4	1116M	Preston	2.26	7.74	.85	13999	15697
4	2054M	Preston	3.57	6.21	.85	14218	15882
4	1262C	Preston	1.48	8.39	.90	14069	15764
4	2250C	Preston	3.91	10.11	1.07	13370	15744
17	2056M	Preston	3.22	7.33	1.73	13995	15822
17	2332C	Preston	3.46	8.12	1.45	13869	15861
5	1144M	Randolph	2.82	10.45	1.00	13475	15731
5	1297C	Randolph	1.45	10.10	.98	13718	15693

TABLE 21

UNIT COAL VALUES—(*Concluded*)

State No.	Table No.	County	Analyses of Coal as Received: Moisture	Ash	Sulphur	B. t. u.	"Unit Coal" Basis $\frac{\text{B. t. u.} - 5000\text{ S}}{1.00 - (1.08\text{ Ash} + {}^{22}/_{40}\text{ S.})}$
			Wyoming				
1	1368M	Sheridan......	22.00	3.37	.60	9796	13192
	1479C	Sheridan......	22.63	4.50	.59	9734	13444
2	1376M	Weston.......	8.60	21.90	4.94	9709	14550
	1571C	Weston.......	9.44	20.72	3.91	9650	14320
	2131C	Weston.......	8.93	20.79	4.03	10001	14757
3	1976M	Crook.........	17.74	11.55	7.03	9527	13918
	2278C	Crook.........	15.12	16.70	6.66	8928	13604
4	3160M	Carbon........	12.32	5.19	.23	11102	13534
	3363C	Carbon........	11.30	7.31	.28	10755	13316
	3396C	Carbon........	12.40	6.77	.26	10706	13341
5	3164M	Sweetwater....	12.41	2.52	.80	11920	14071
	3213C	Sweetwater....	11.64	3.41	.81	11768	13923
6	3202M	Uinta.........	20.57	2.63	.51	10237	13383
	3390C	Uinta.........	19.00	3.12	.49	10307	13293
			Alaska				
2479	....	....	4.43	4.65	.51	13640	15083
2483	....	....	13.89	7.23	.82	12137	15537
2219	....	....	6.74	12.47	.44	11968	15017
2222	....	....	2.55	6.05	.57	13711	15101
2224	....	....	6.60	10.87	.41	11338	13898
2227	....	....	.90	4.90	.60	14868	15873
			Argentina, South America				
4079C	....	....	7.67	42.85	1.21	6320	13792
			Brazil, South America				
172	....	Dry Coal......	......	27.54	3.02	10028	14398
173	....	Dry Coal......	......	27.84	4.53	9830	14241

Bulletin No. 1. Tests of Reinforced Concrete Beams, by Arthur N. Talbot. 1904. (*Out of print*).

Circular No. 1. High-Speed Tool Steels, by L. P. Breckenridge. 1905. (*Out of print*).

Bulletin No. 2. Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and Henry B. Dirks. 1905. (*Out of print*).

Circular No. 2. Drainage of Earth Roads, by Ira O. Baker. 1906. (*Out of print*).

Circular No. 3. Fuel Tests with Illinois Coal. (Compiled from tests made by the Technologic Branch of the U. S .G. S., at the St. Louis, Mo., Fuel Testing Plant, 1904-1907, by L. P. Breckenridge and Paul Diserens. 1909.

Bulletin No. 3. The Engineering Experiment Station of the University of Illinois, by L. P. Breckenridge. 1906. (*Out of print*).

Bulletin No. 4. Tests of Reinforced Concrete Beams, Series of 1905, by Arthur N. Talbot. 1906.

Bulletin No. 5. Resistance of Tubes to Collapse, by Albert P. Carman. 1906. (*Out of print*).

Bulletin No. 6. Holding Power of Railroad Spikes, by Roy I. Webber. 1906. (*Out of print*).

Bulletin No. 7. Fuel Tests with Illinois Coals, by L. P. Breckenridge, S. W. Parr, and Henry B. Dirks. 1906.

Bulletin No. 8. Tests of Concrete: I. Shear; II. Bond, by Arthur N. Talbot. 1906. (*Out of print*).

Bulletin No. 9. An Extension of the Dewey Decimal System of Classification Applied to the Engineering Industries, by L. P. Breckenridge and G. A. Goodenough. 1906. (*Out of print*).

Bulletin No. 10. Tests of Concrete and Reinforced Concrete Columns, Series of 1906, by Arthur N. Talbot. 1907. (*Out of print*).

Bulletin No. 11. The Effect of Scale on the Transmission of Heat through Locomotive Boiler Tubes, by Edward C. Schmidt and John M. Snodgrass. 1907. (*Out of print*).

Bulletin No. 12. Tests of Reinforced Concrete T-beams, Series of 1906, by Arthur N. Talbot. 1907. (*Out of print*).

Bulletin No. 13. An Extension of the Dewey Decimal System of Classification Applied to Architecture and Building, by N. Clifford Ricker. 1907.

Bulletin No. 14. Tests of Reinforced Concrete Beams, Series of 1906, by Arthur N. Talbot. 1907. (*Out of print*).

Bulletin No. 15. How to Burn Illinois Coal without Smoke, by L. P. Breckenridge. 1908

Bulletin No. 16. A Study of Roof Trusses, by N. Clifford Ricker. 1908.

Bulletin No. 17. The Weathering of Coal, by S. W. Parr, N. D. Hamilton, and W. F. Wheeler. 1908. (*Out of print*).

Bulletin No. 18. The Strength of Chain Links, by G. A. Goodenough and L. E. Moore. 1908.

Bulletin No. 19. Comparative Tests of Carbon, Metallized Carbon and Tantalum Filament Lamps, by T. H. Amrine. 1908. (*Out of print*).

Bulletin No. 20. Tests of Concrete and Reinforced Concrete Columns, Series of 1907, by Arthur N. Talbot. 1908. (*Out of print*).

Bulletin No. 21. Tests of a Liquid Air Plant, by C. S. Hudson and C. M. Garland. 1908.

Bulletin No. 22. Tests of Cast-Iron and Reinforced Concrete Culvert Pipe, by Arthur N. Talbot. 1908.

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Bulletin No. 28. A Test of Three Large Reinforced Concrete Beams, by Arthur N. Talbot. 1909.

Bulletin No. 29. Tests of Reinforced Concrete Beams: Resistance to Web Stresses, by Arthur N. Talbot, 1909.

Bulletin No. 30. On the Rate of Formation of Carbon Monoxide in Gas Producers, by J. K. Clement, L. H. Adams and C. N. Haskins. 1909.

Bulletin No. 31. Fuel Tests with House-heating Boilers, by J. M. Snodgrass. 1909.

Bulletin No. 32. Occluded Gases in Coal, by S. W. Parr and Perry Barker. 1909.

Bulletin No. 33. Tests of Tungsten Lamps, by T. H. Amrine and A. Guell. 1909.

Bulletin No. 34. Tests of Two Types of Tile Roof Furnaces under a Water-tube Boiler, by J. M. Snodgrass. 1909.

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Bulletin No. 36. The Thermal Conductivity of Fire Clay at High Temperetures, by J. K. Clement and W. L. Egy. 1909.

Bulletin No. 37. Unit Coal and the Composition of Coal Ash, by S. W. Parr and W. F Wheeler. 1909.